The STAR Transverse Spin Programme

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RIKEN Forward Physics Workshop

Brookhaven National Lab

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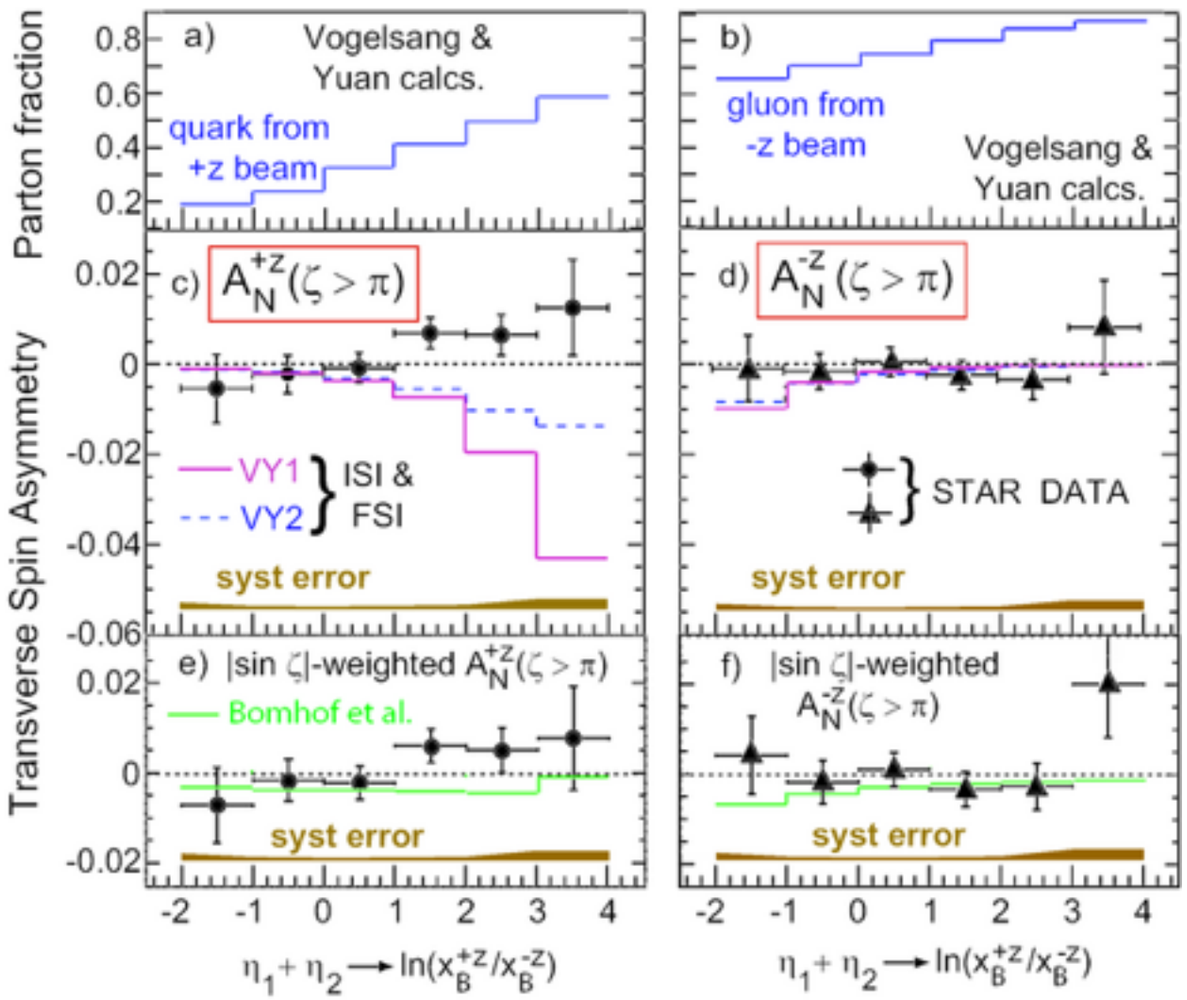
Introduction

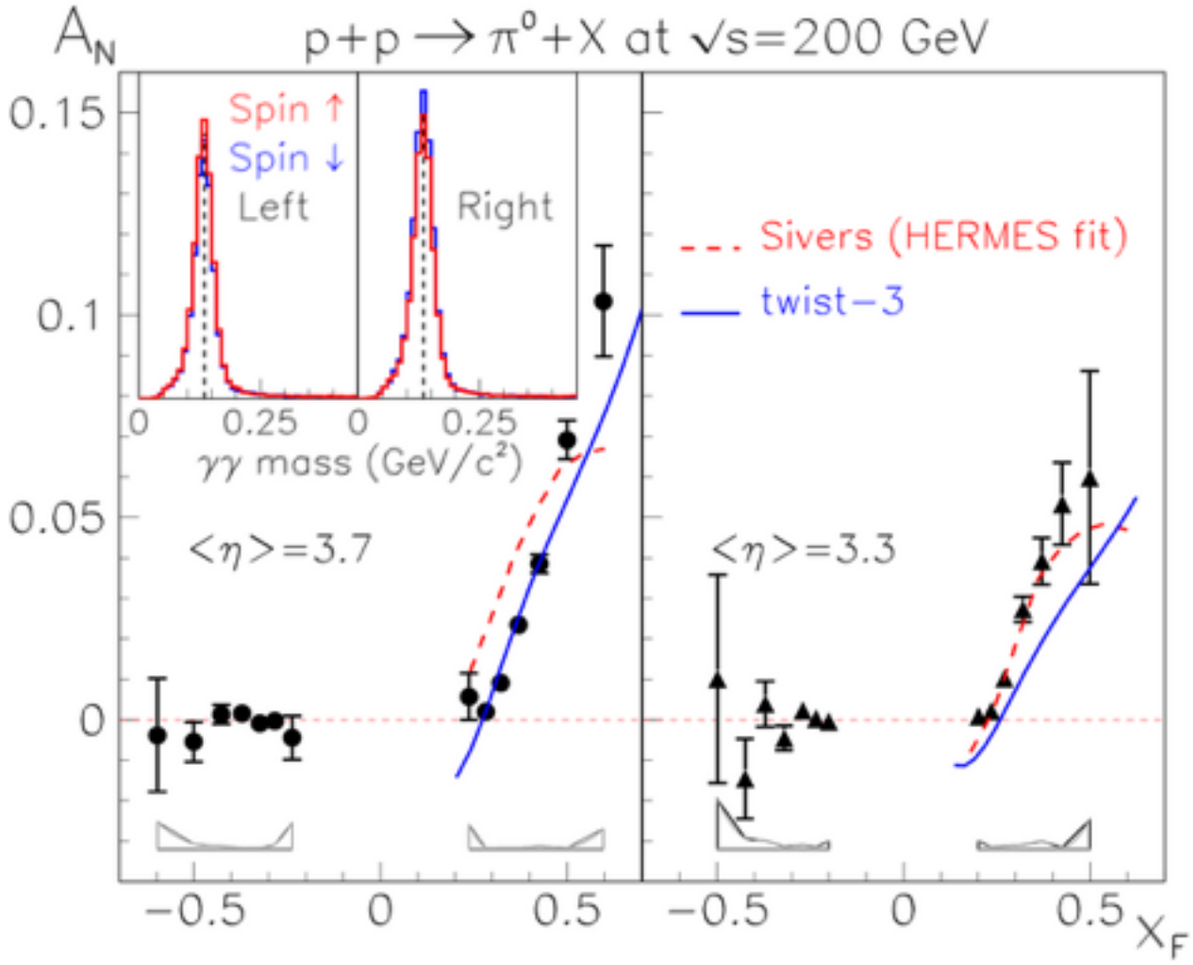
- Recent results from STAR transverse spin
- Future: what measurements do we want to make?
  - A_N: Disentagle Sivers, Collins OR other mechanisms
  - A Sivers sign change between DIS and DY?
  - Nucleon structure: flavour decomposition, GPDs
- Upgrade plans - what do we need to add/change?

Past results

Midrapidity: Sivers jet measurement shows no asymmetry



Forward: Large asymmetries in π^0 production



Recent Results

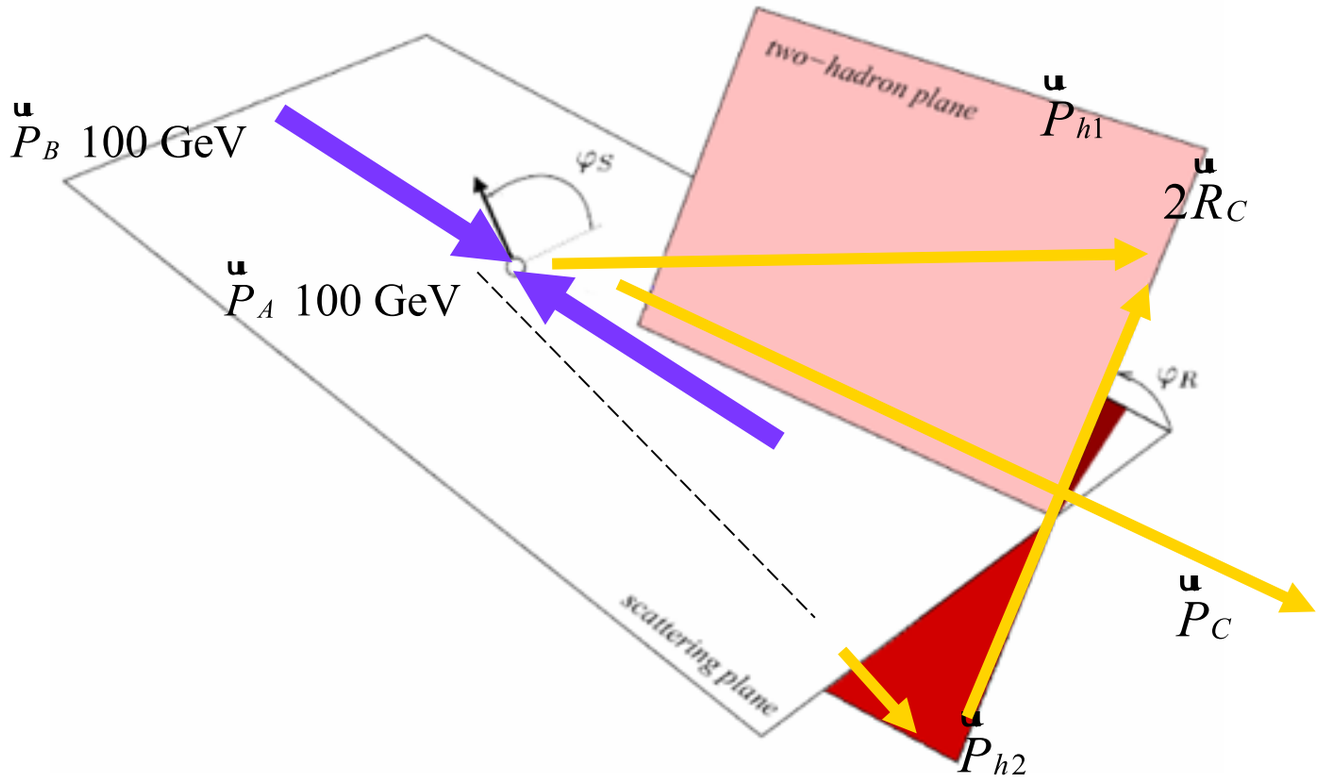
1. **Midrapidity**: transversity and spin-dependent fragmentation
    1. IFF
    2. Collins in jets
2. **Forward**: transverse single-spin asymmetries
    1. π^0/η asymmetries
    2. 2011 π^0

Midrapidity IFF

- **I**nterference **F**ragmentation **F**unction:
  - Spin-dependent dihadron production
- $\sin(\phi_S - \phi_R)$ modulation of hadron pair

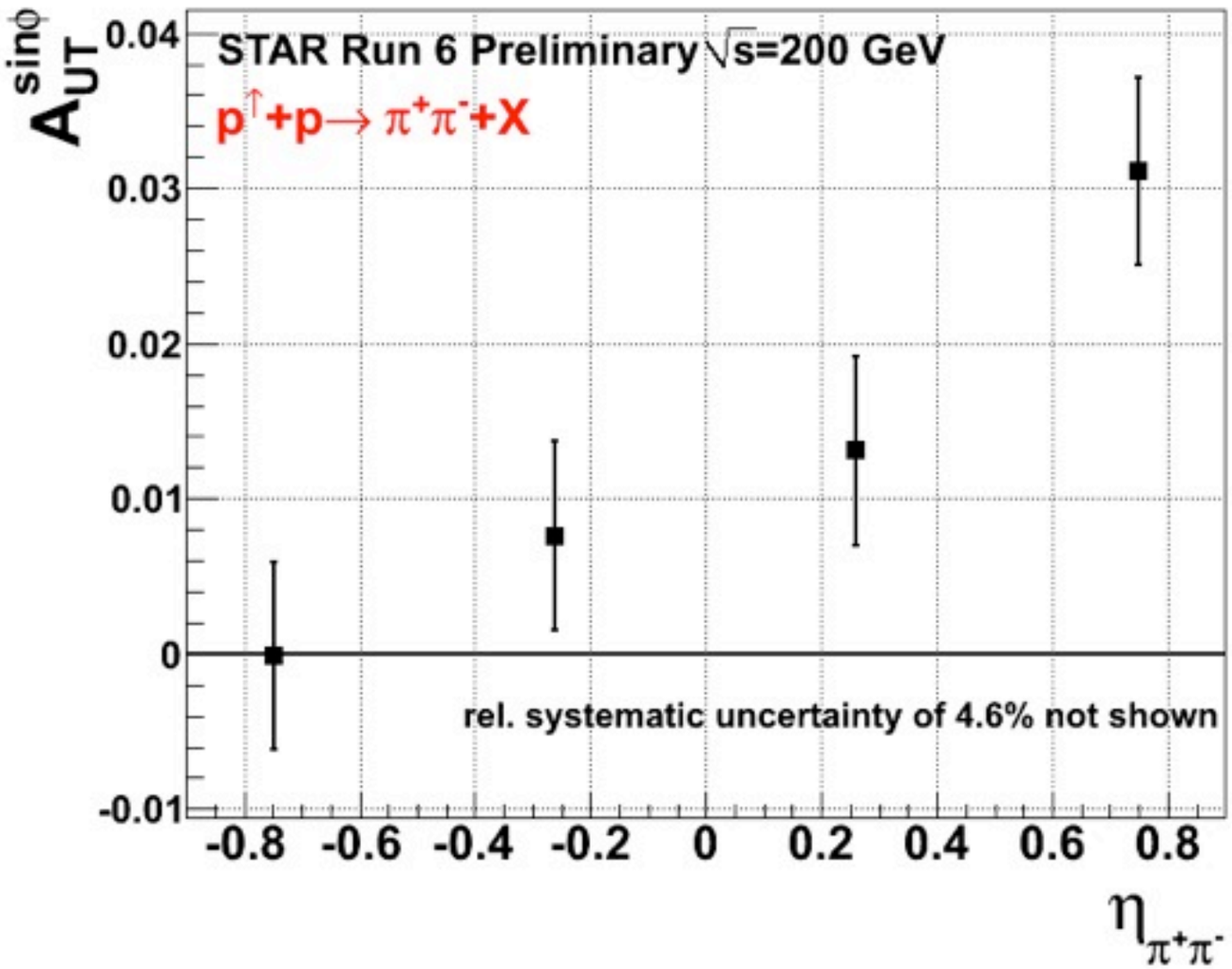
asymmetry ∝

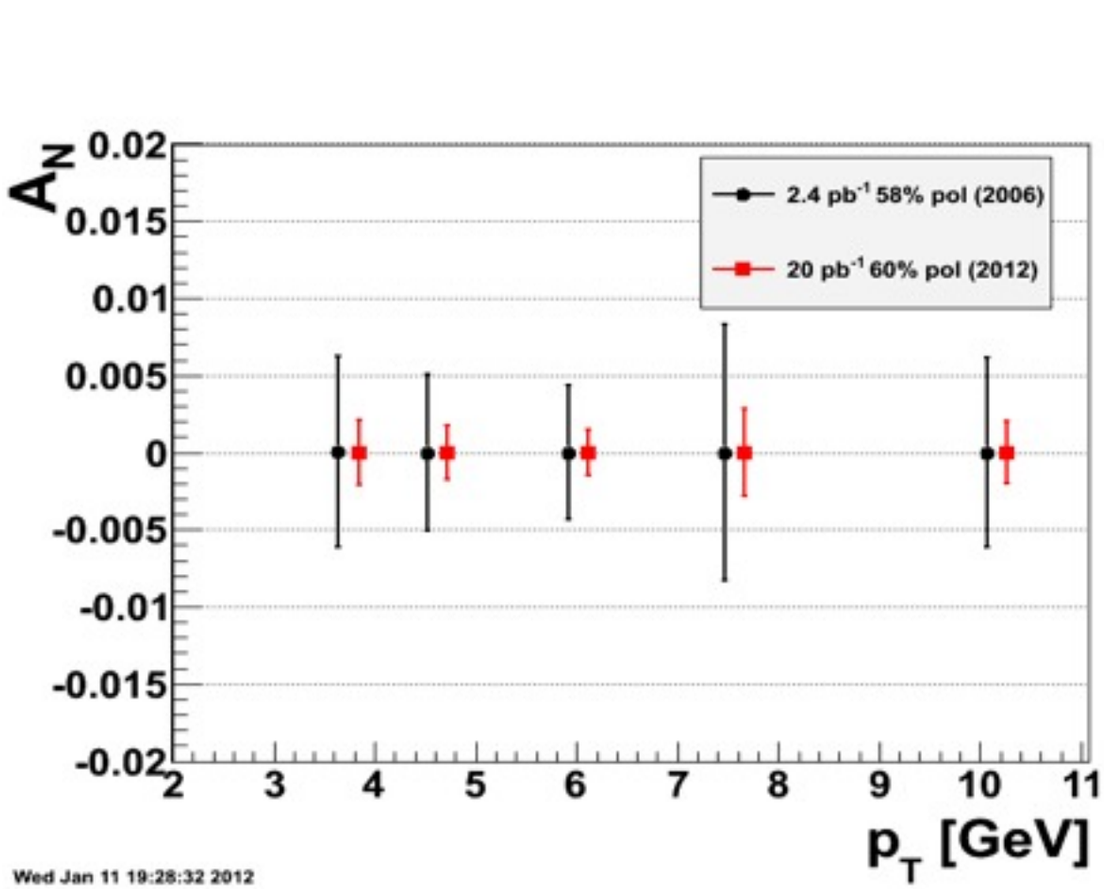
transversity ⊗ IFF



Midrapidity IFF

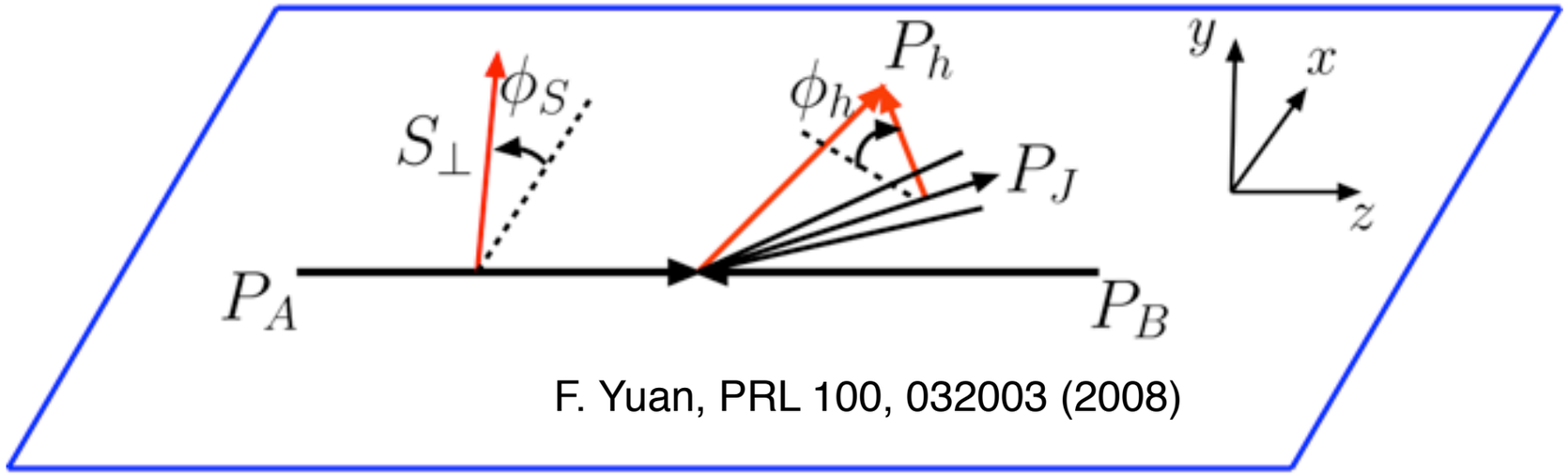
- Non-zero: **midrapidity transversity**
- More data on the way



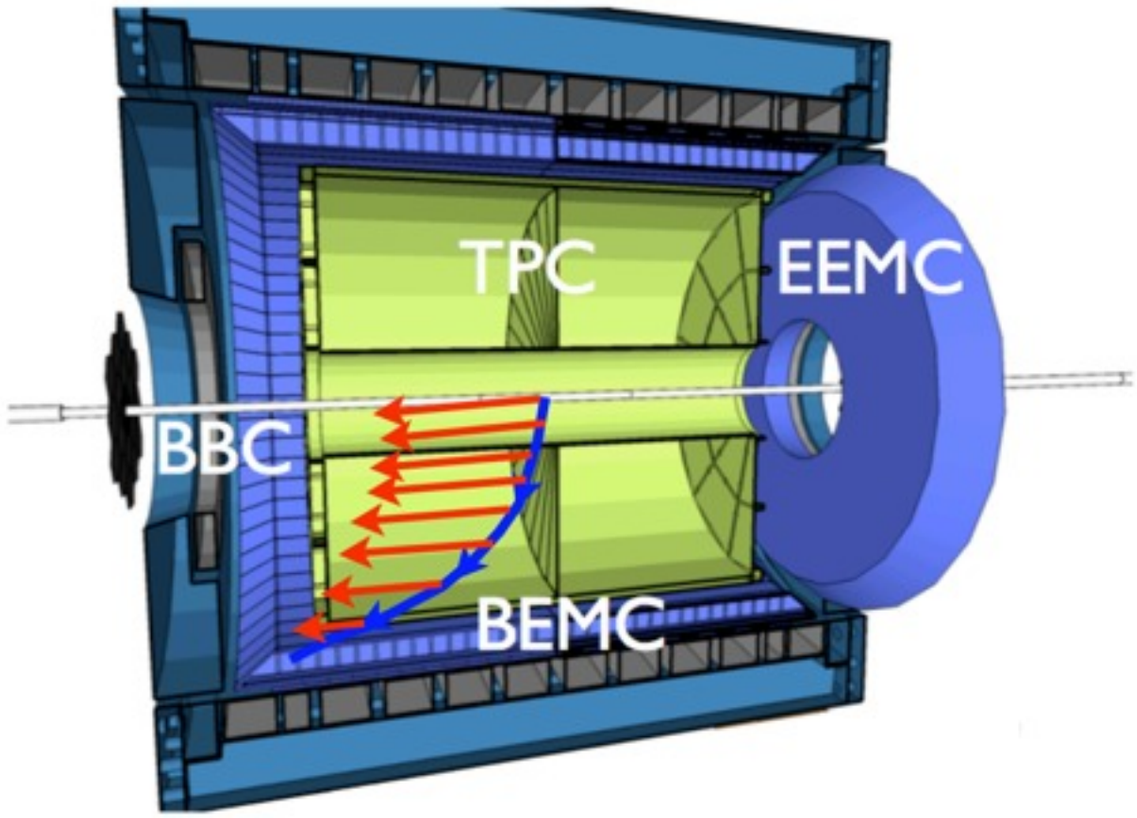


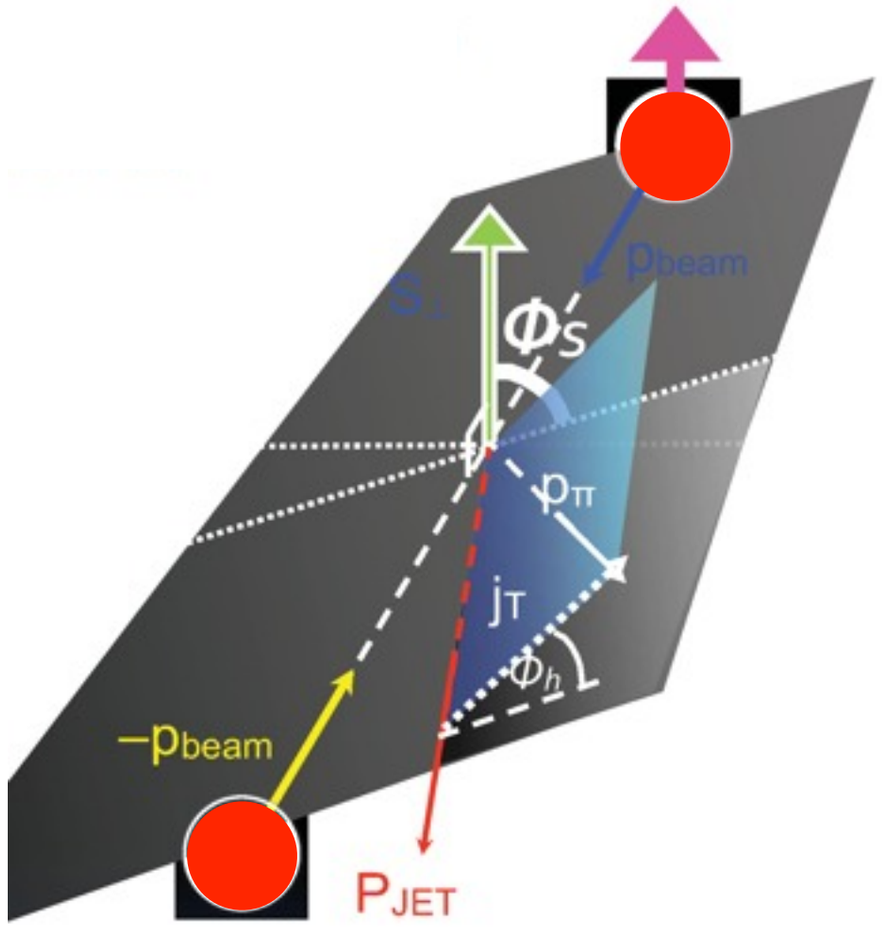
Midrapidity jet Collins

- Measure an azimuthal modulation of π in a jet

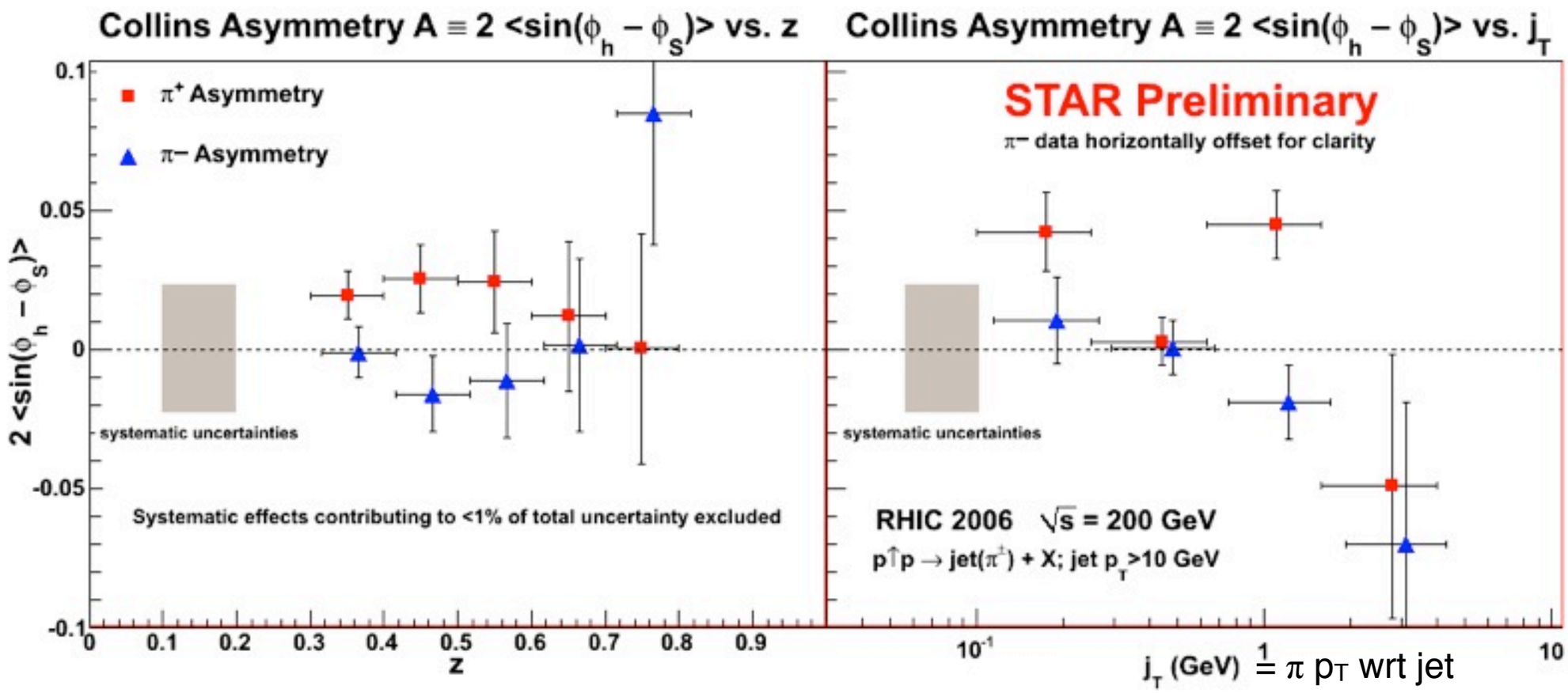


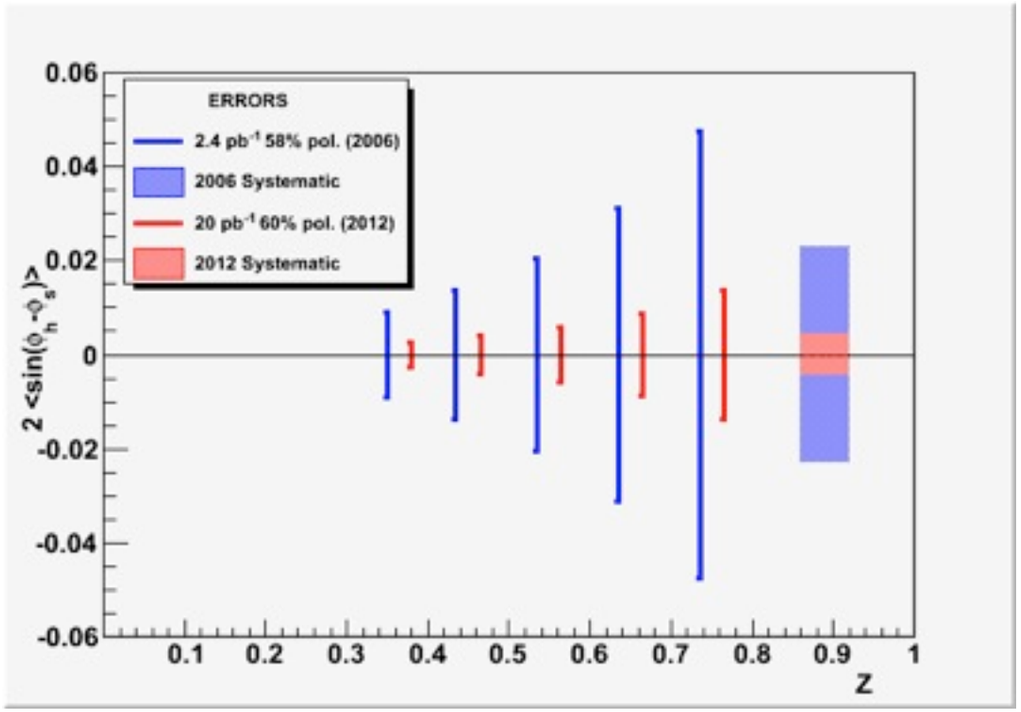
F. Yuan, PRL 100, 032003 (2008)





Midrapidity jet Collins

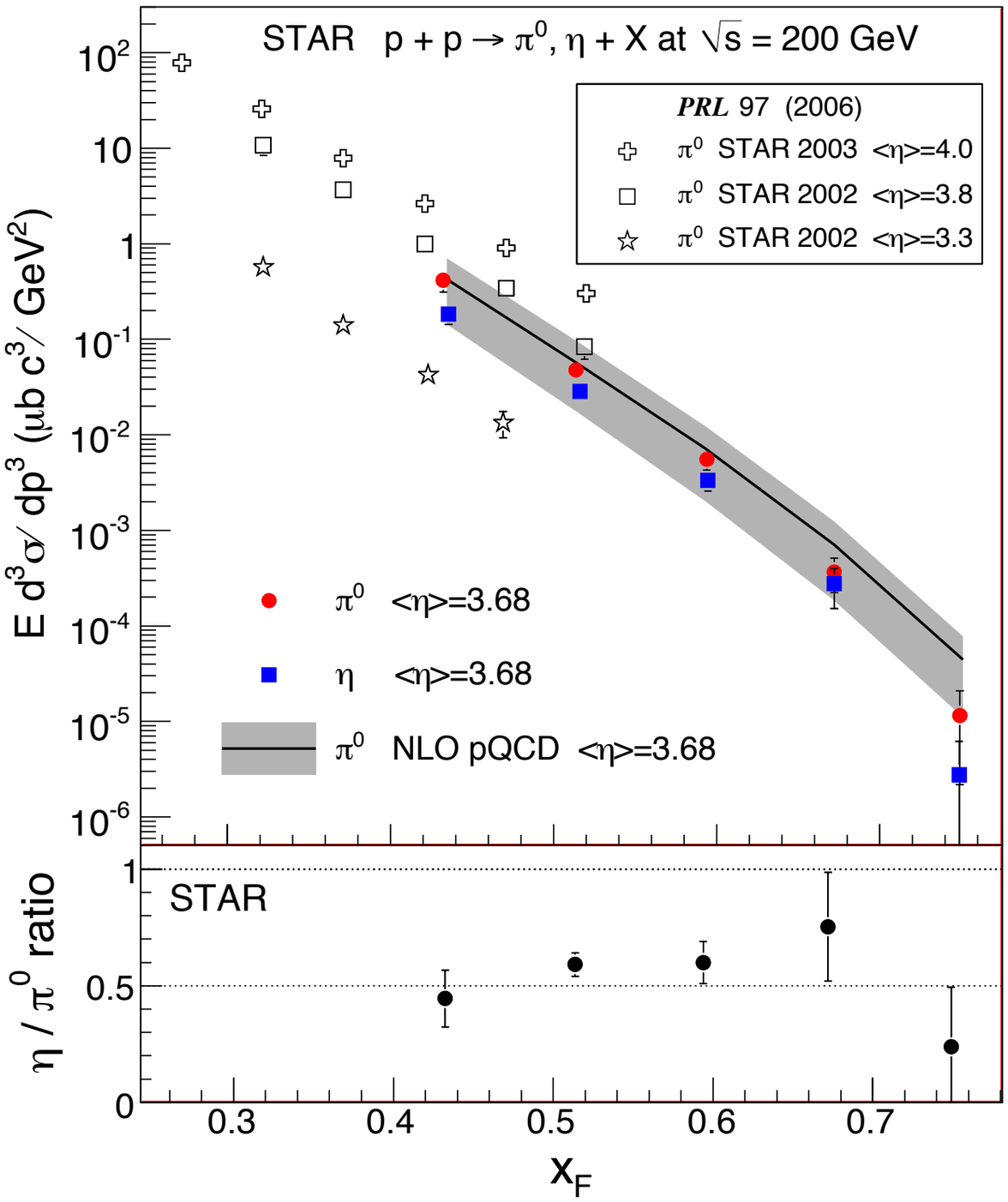




- Sign difference?
- Run 12 data should clarify

Forward π^0/η asymmetry

- π^0/η in forward EM calorimeter (FMS)
- σ described by pQCD
- A_N^{η} comparable to or greater than π^0
  - Different ff, flavour structure



- Len Eun (award-winning thesis!)
  - Thesis: http://arxiv.org/abs/1205.4771
  - Paper submitted to PRDhttp://arxiv.org/pdf/1205.6826v1.pdf

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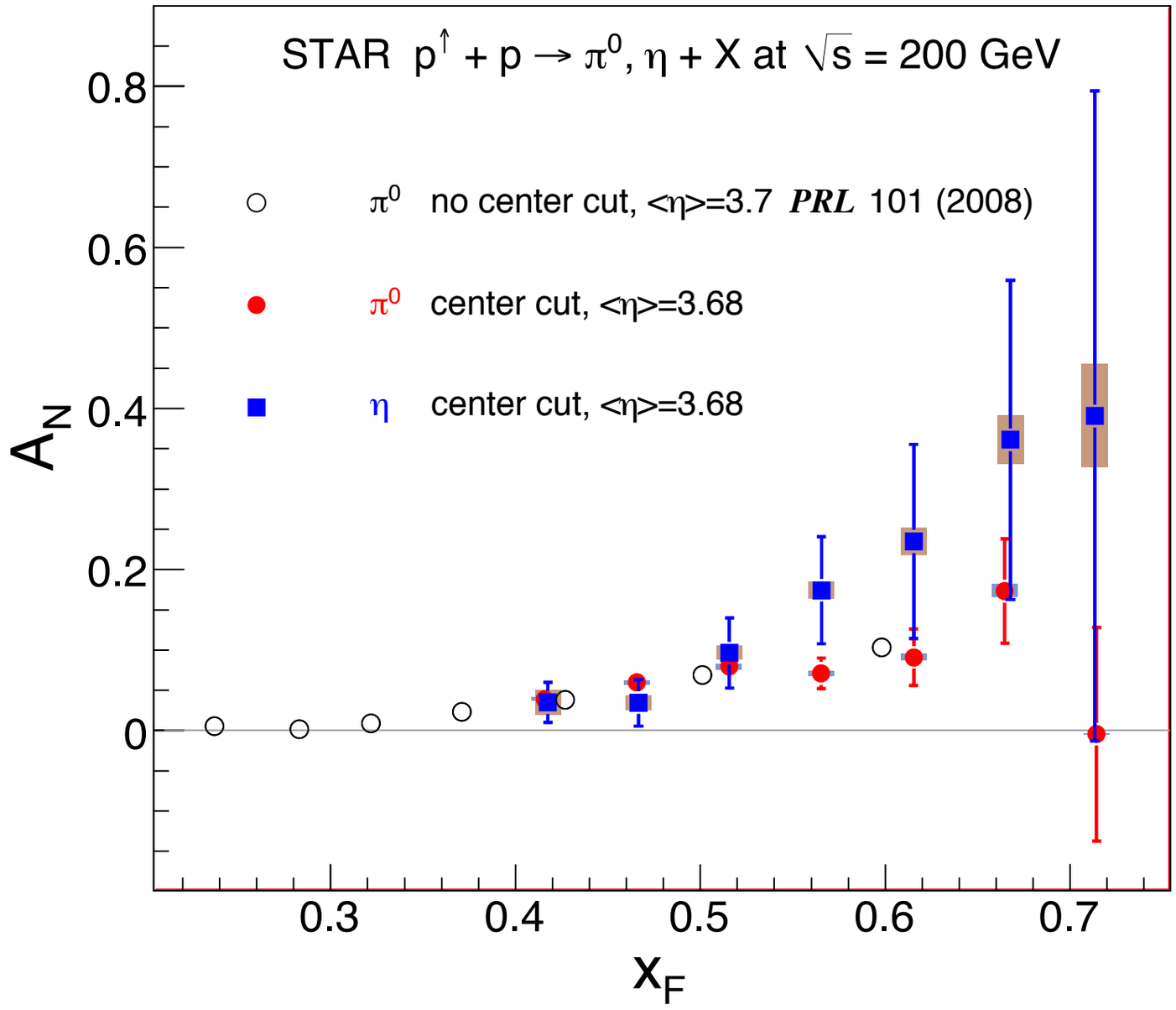

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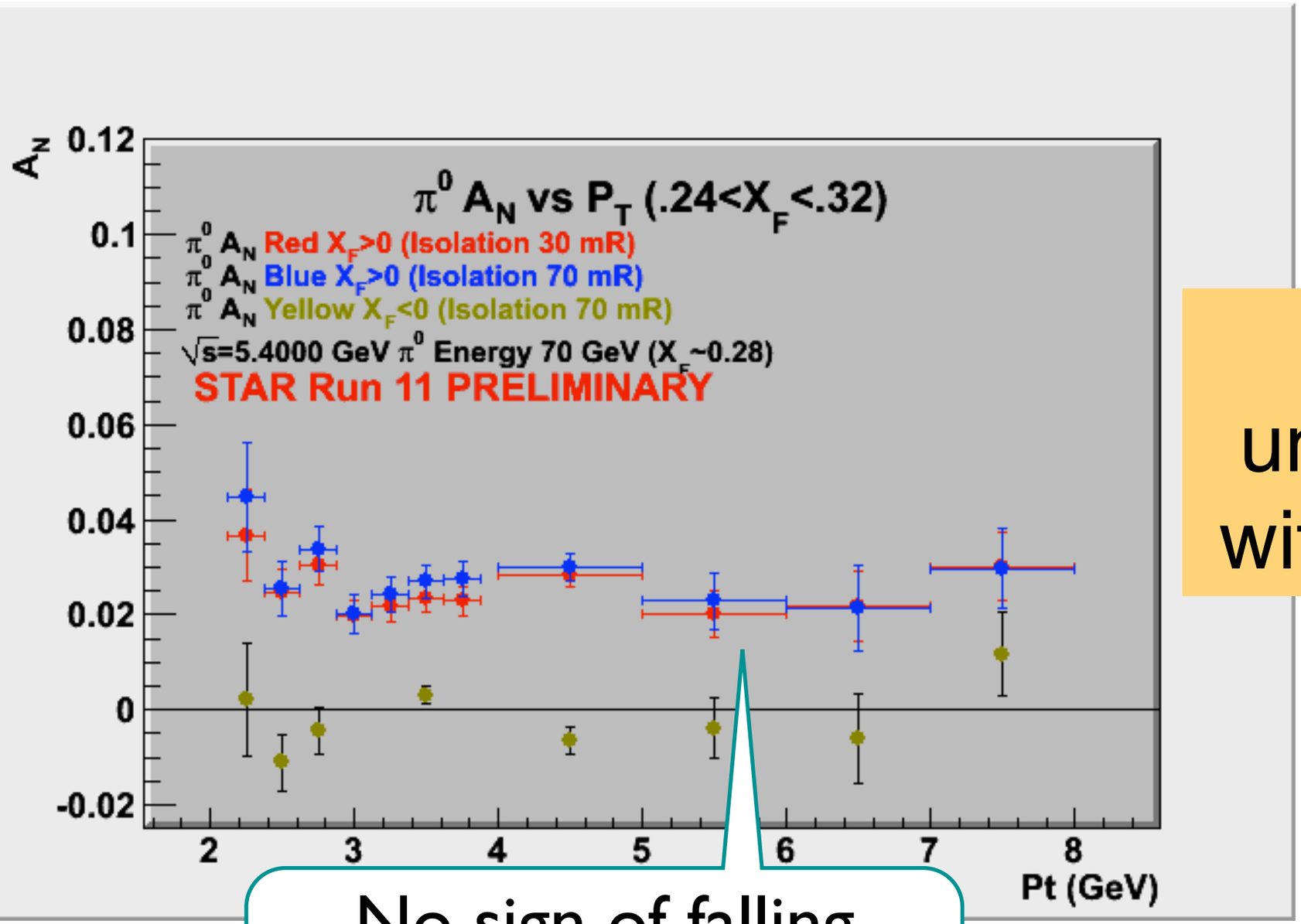
2011 forward pi0



How can we understand this with e.g. Sivers?

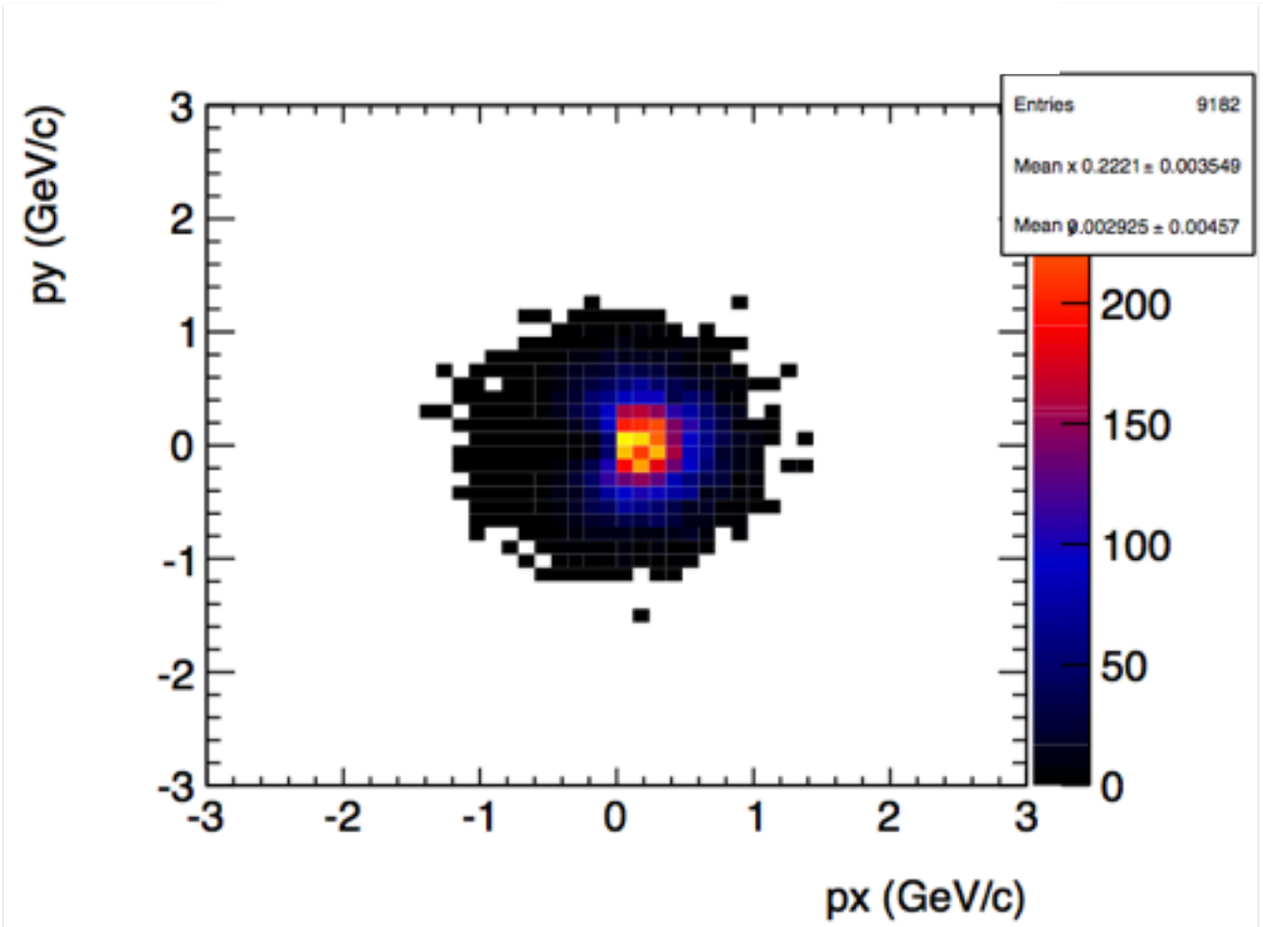
No sign of falling with p_T - not what we expect from pQCD

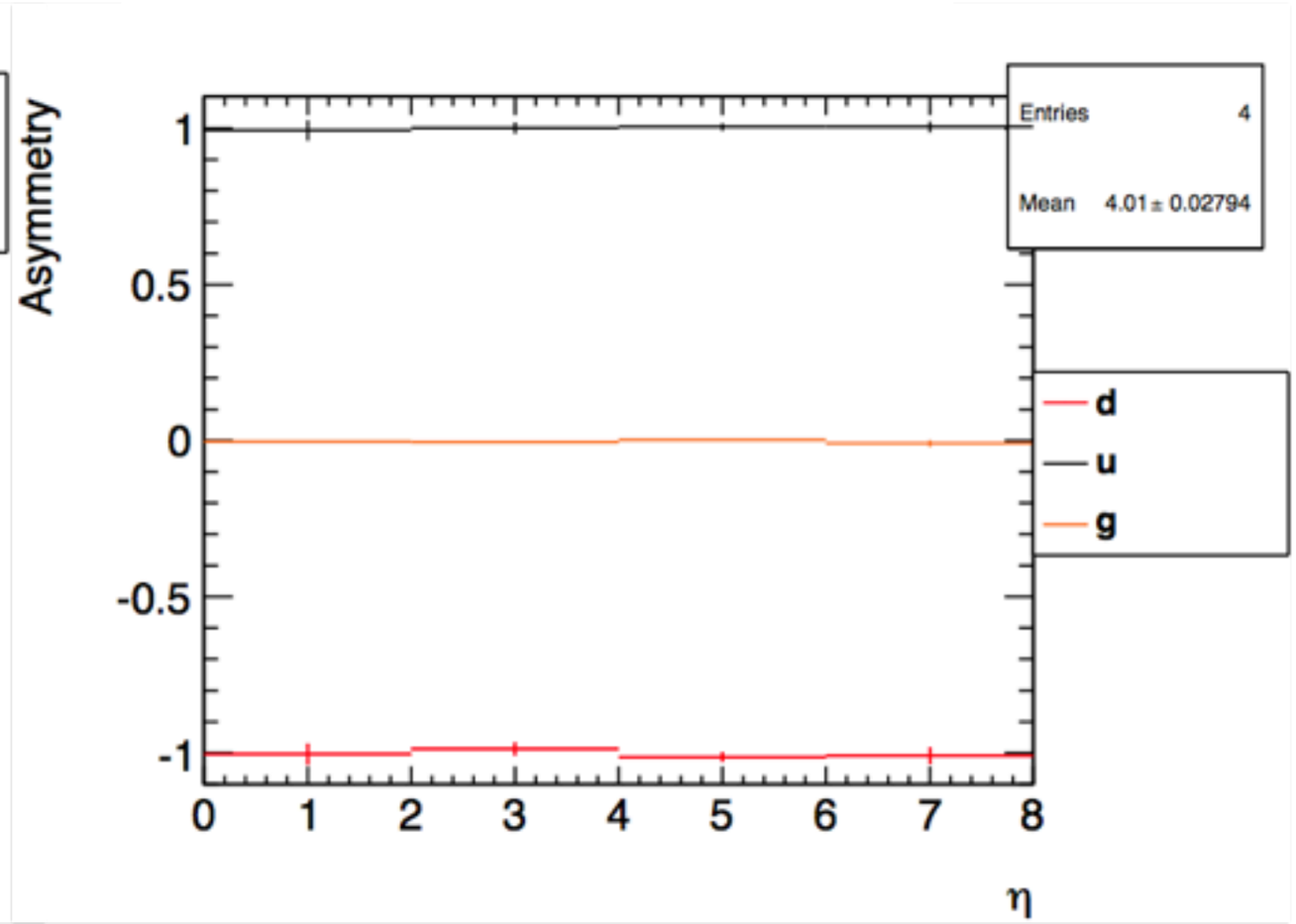
Simple Monte Carlo

- Use weighted PYTHIA

  Weight partons: 1 + (sivers/unpol)*(px/p_T)*(amplitude*spin factor)

  ➡ ϕ modulation in momentum distribution





Incident partons: 100% input asymmetry

Simple Monte Carlo

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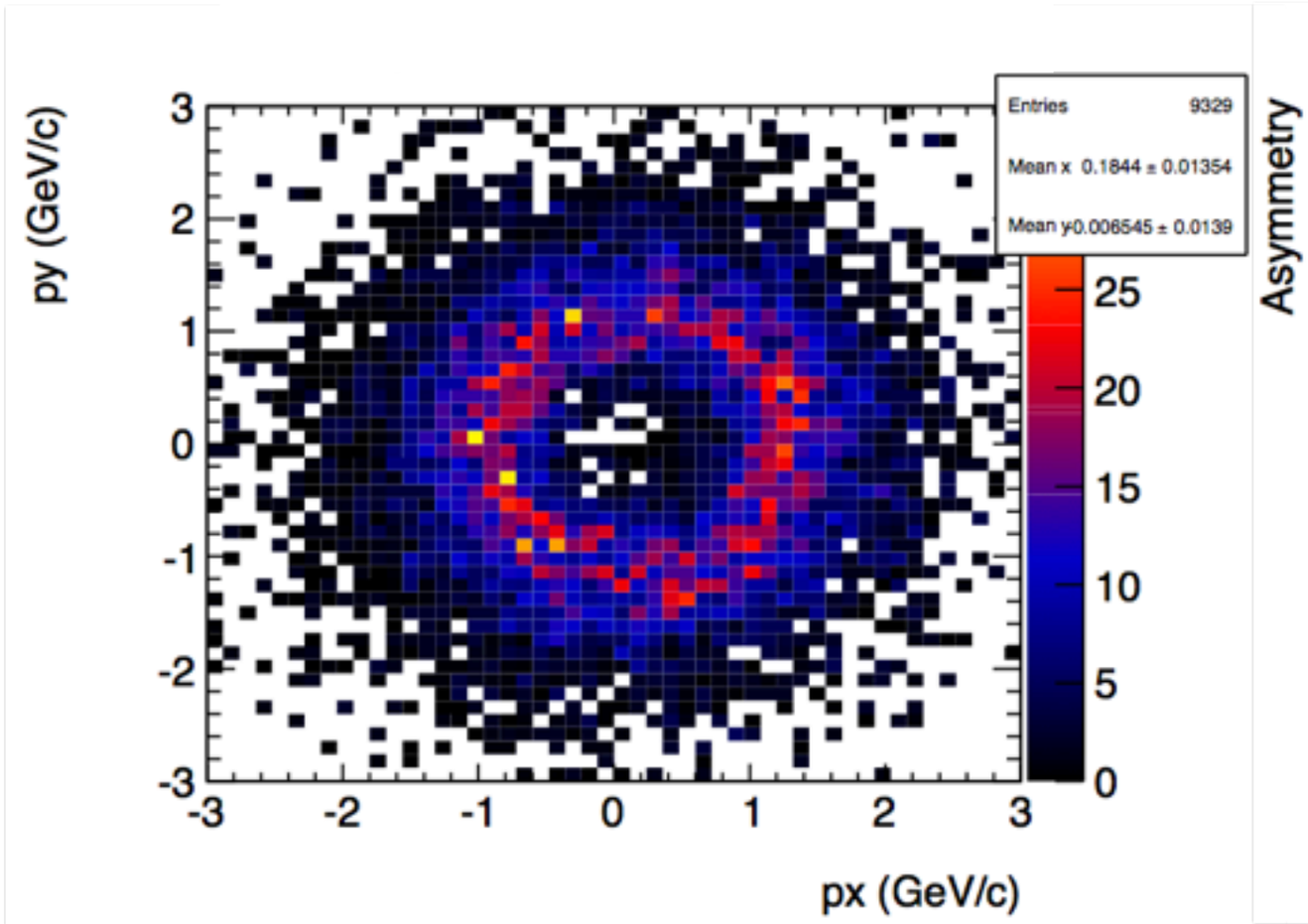
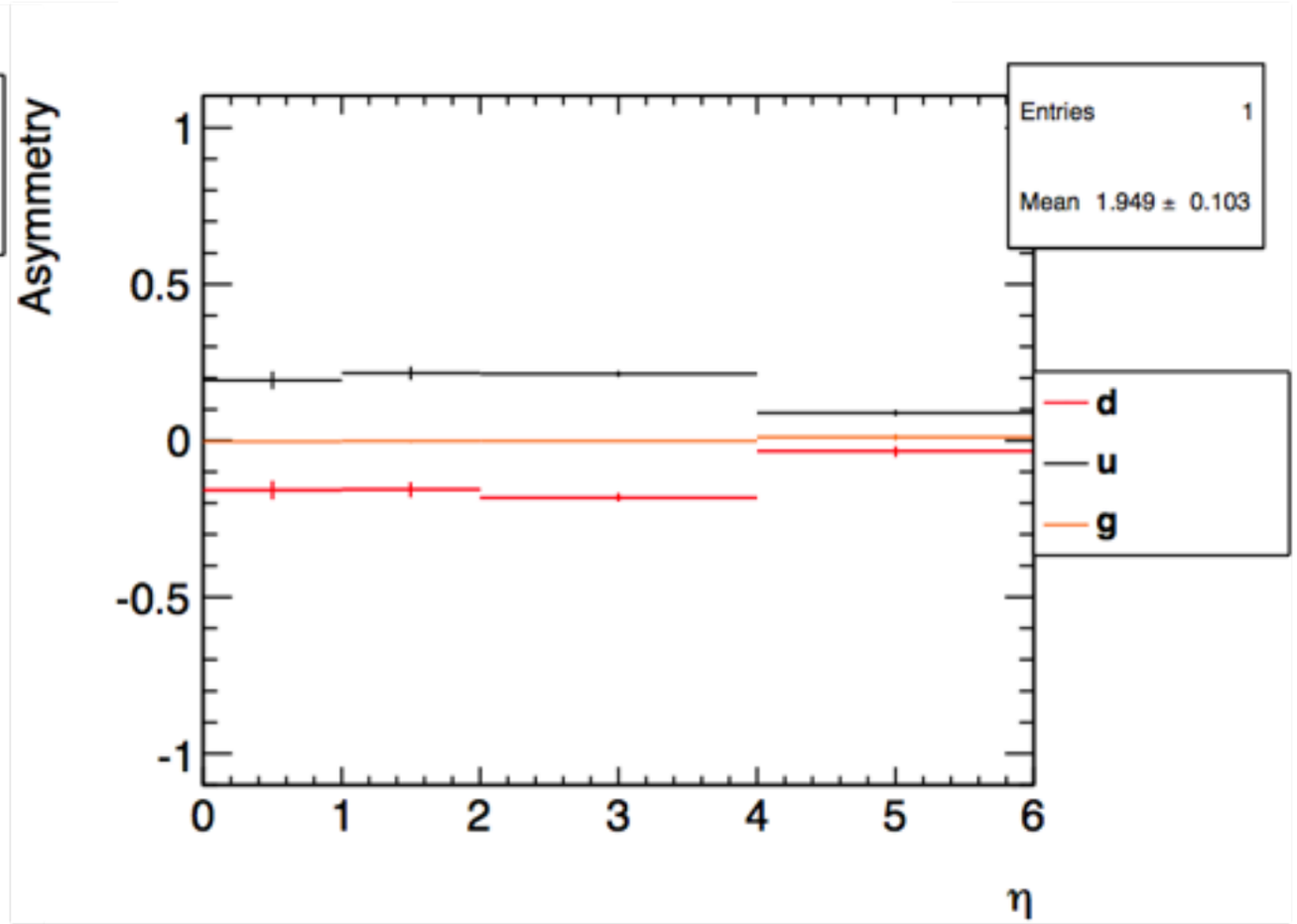
  ➡ ϕ modulation in momentum distribution





Scattered partons: hard p_T >> intrinsic k_T

→asymmetry watered down

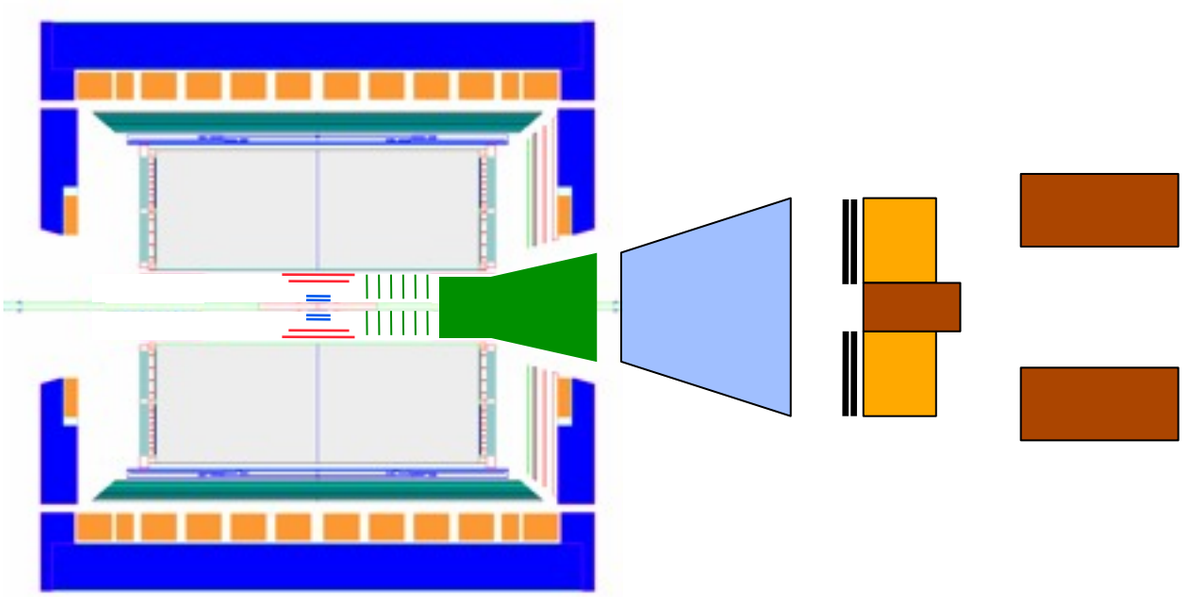
Summary

- Midrapidity: see
  - **transversity** &
  - **spin-dependent fragmentation**
  - Can extend to $\eta < 2$ with FGT + EEMC

- Forward:
  - **Large** asymmetries persist with pT
  - Remains confusing - is it Sivers/twist-3 mechanism? Collins? Something else? All of the above?

Future Directions

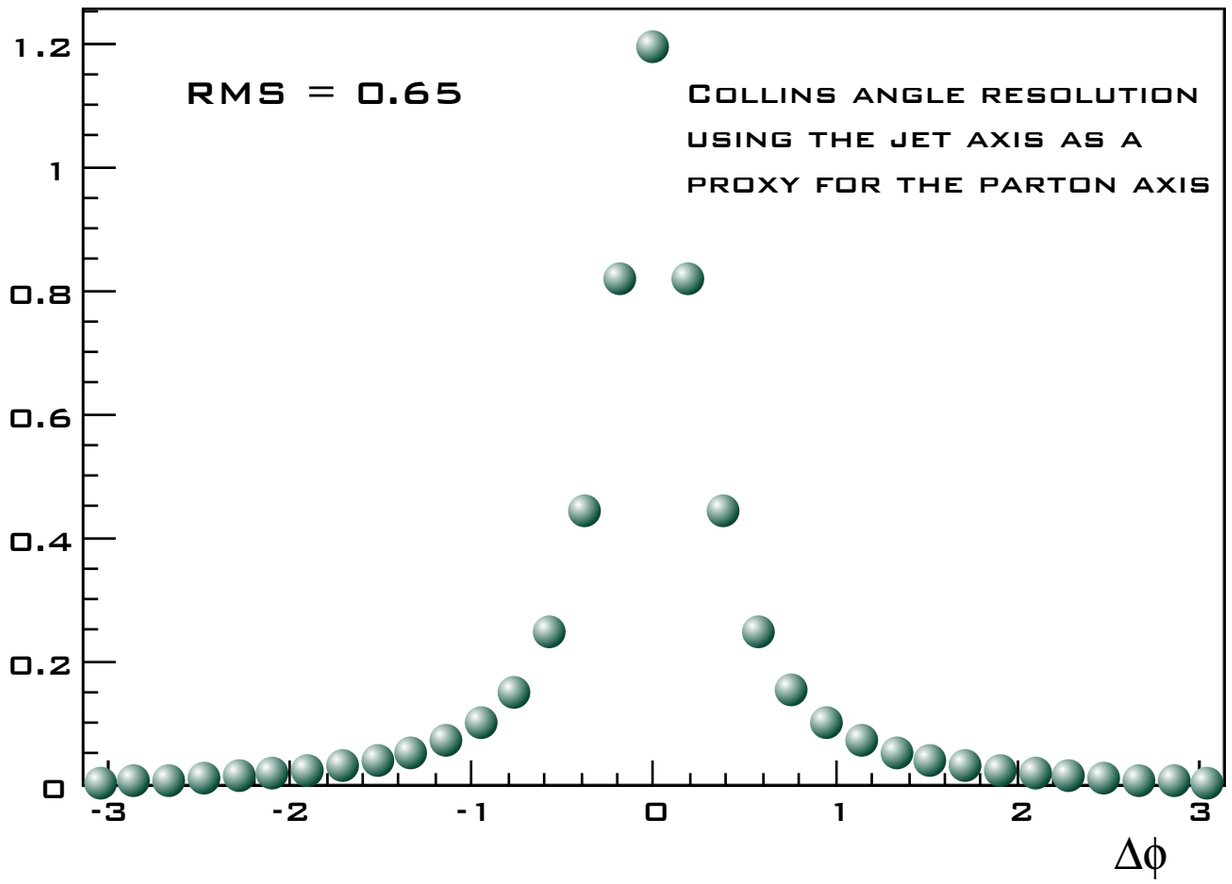
- What physics do we want to study?

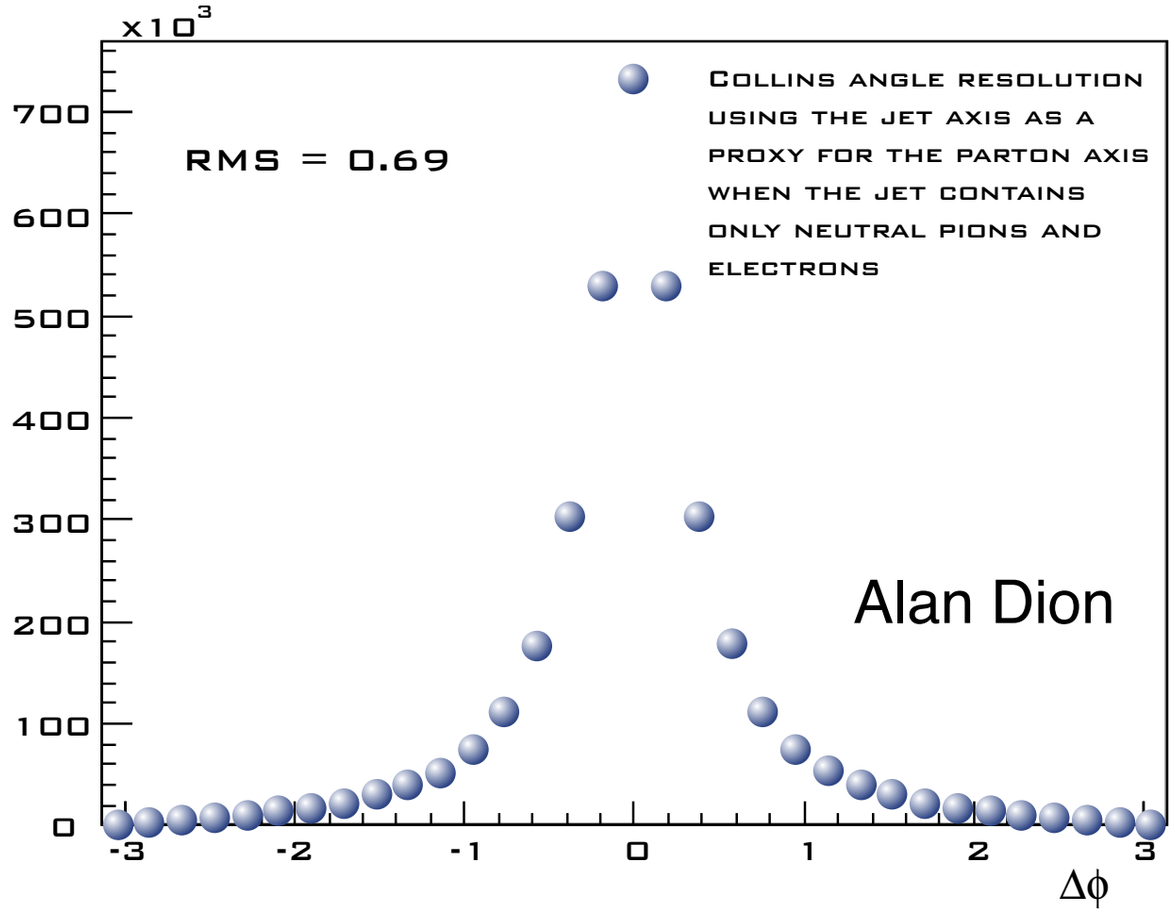


- What upgrades do we need to get there?

Forward jets

- Could we study jets with just extant EMCal?

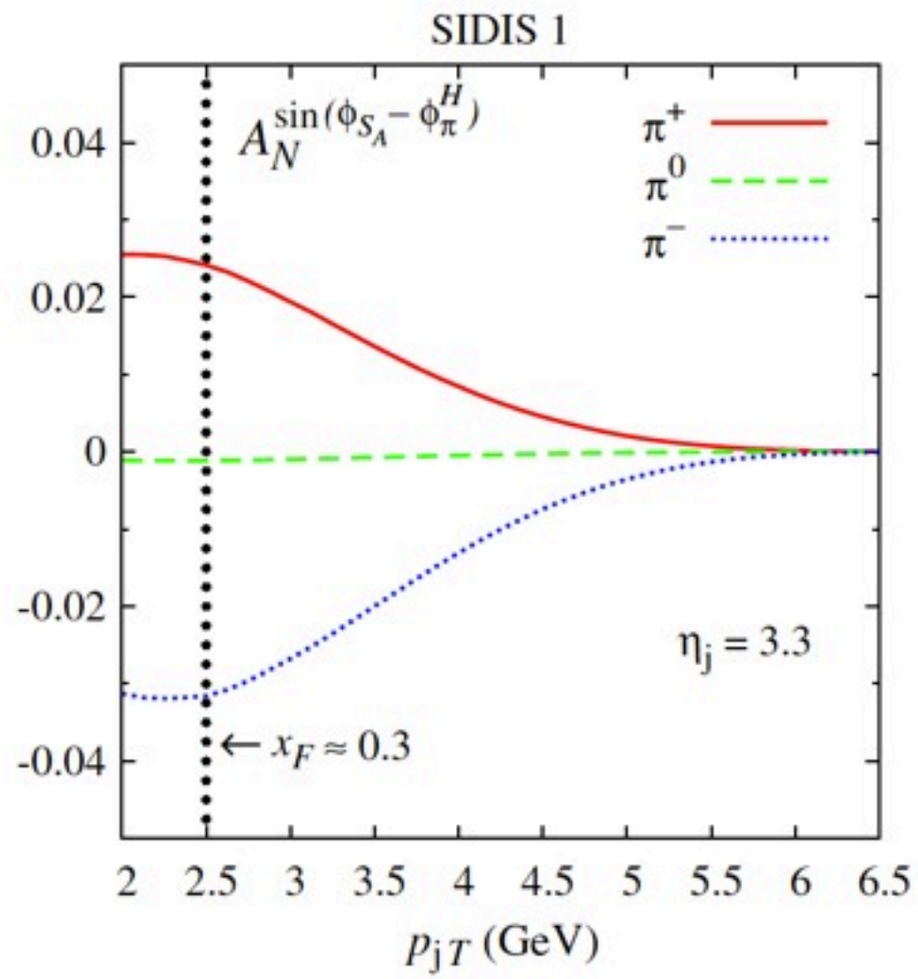


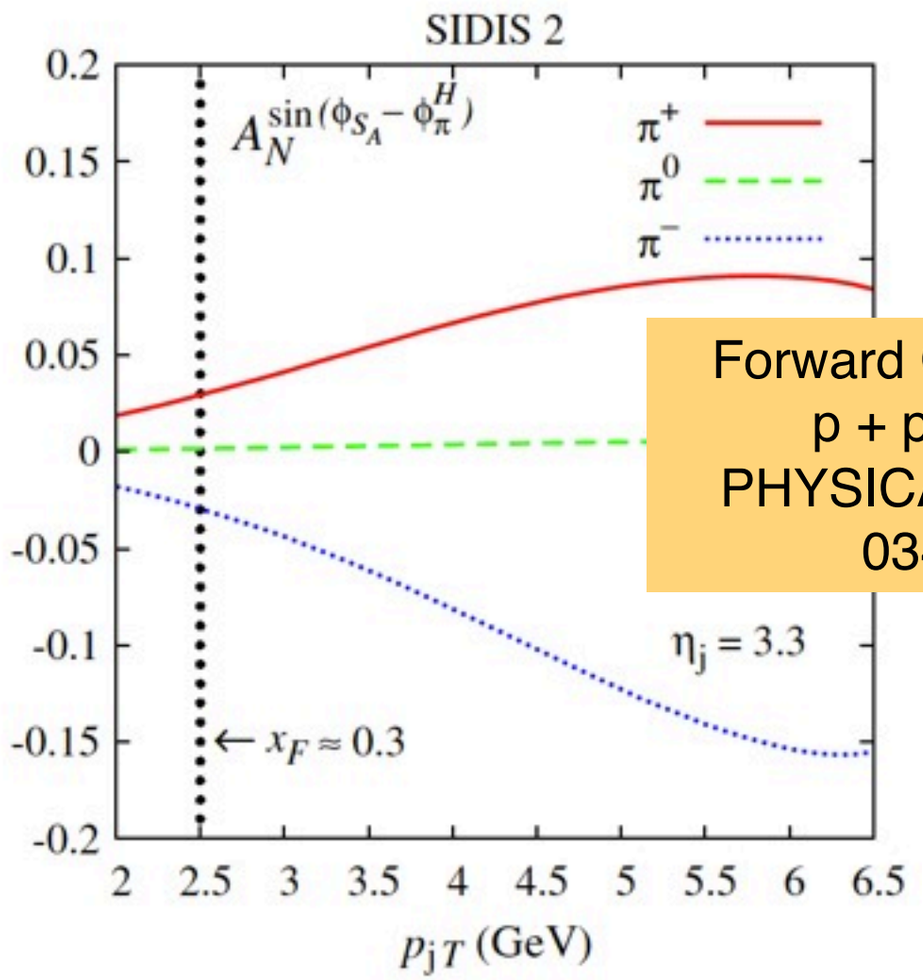


- Bottom line:
  - For just angles: existing EMCal is probably OK
  - For energy/p_T: not enough, need tracking/HCal

Forward Collins

- Large x - essentially unconstrained by SIDIS
- Extend π/jet measurement forward
- Need forward jet capability/PID/tracking

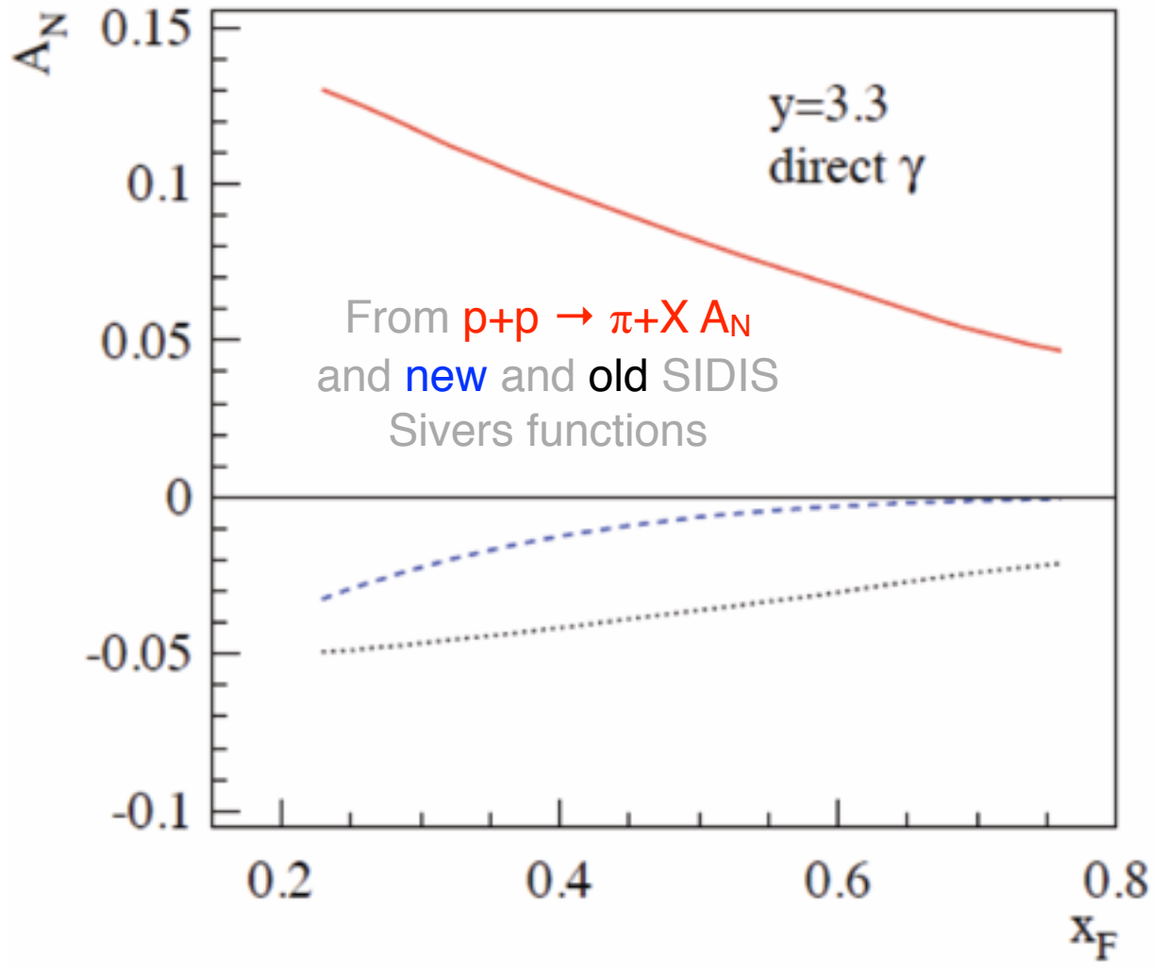




Forward Collins asymmetry
p + p → π + jet + X
PHYSICAL REVIEW D 83, 034021 (2011)

Prompt photons

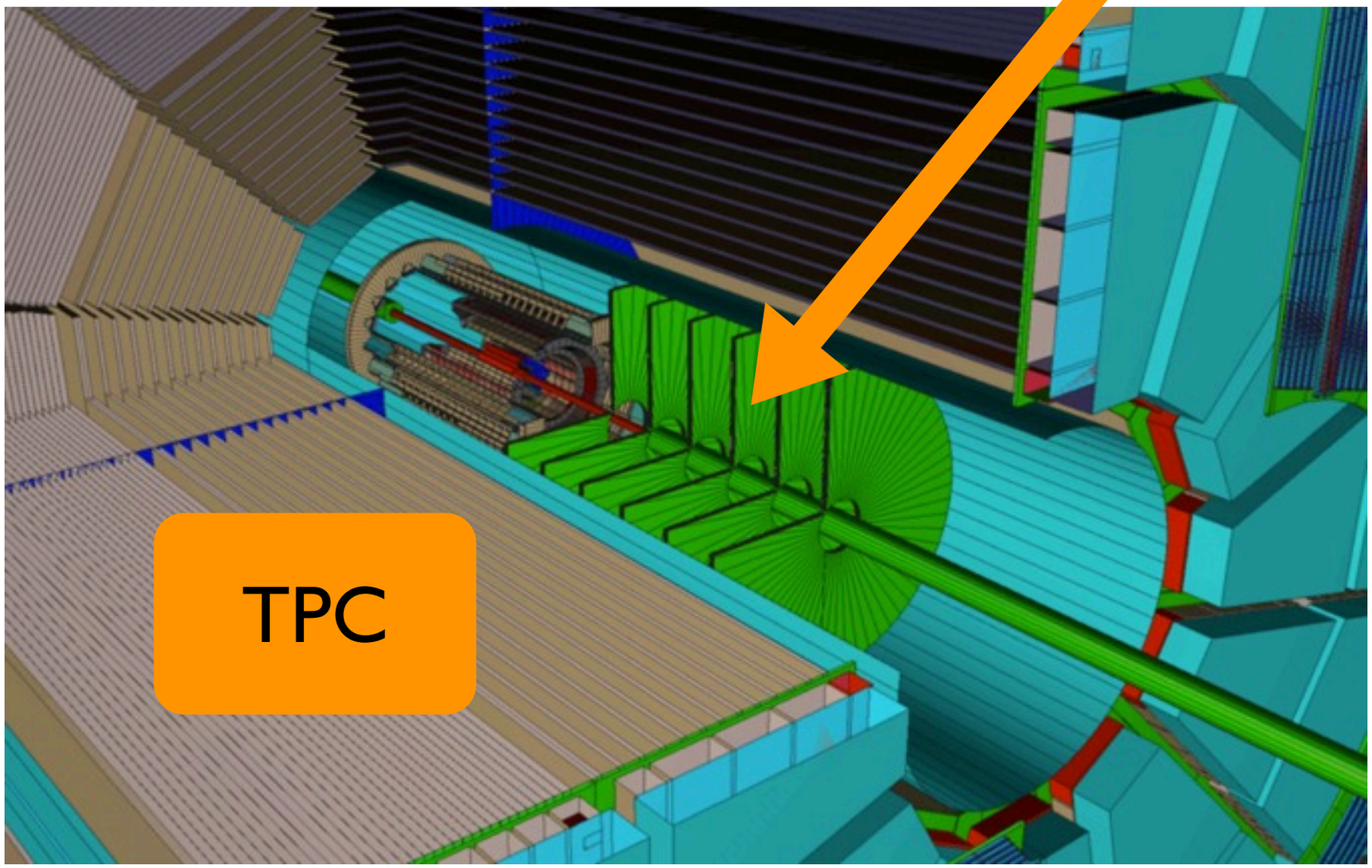
- Measure isolated γ
- Isolate Sivers: no fragmentation
- Potentially large A_N
- Demands luminosity
- Poor knowledge of forward γ cross section



Forward Tracking

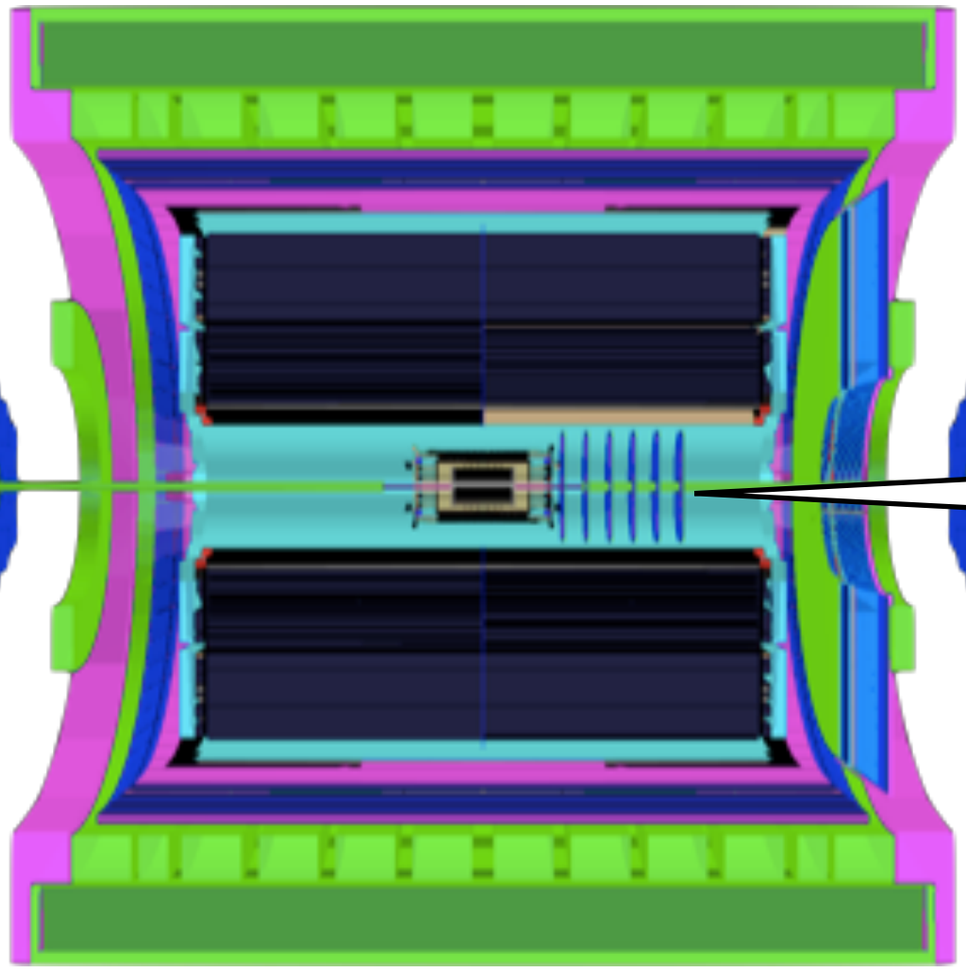
6 layers, tracking $1 < \eta < 2$

Commissioned this year

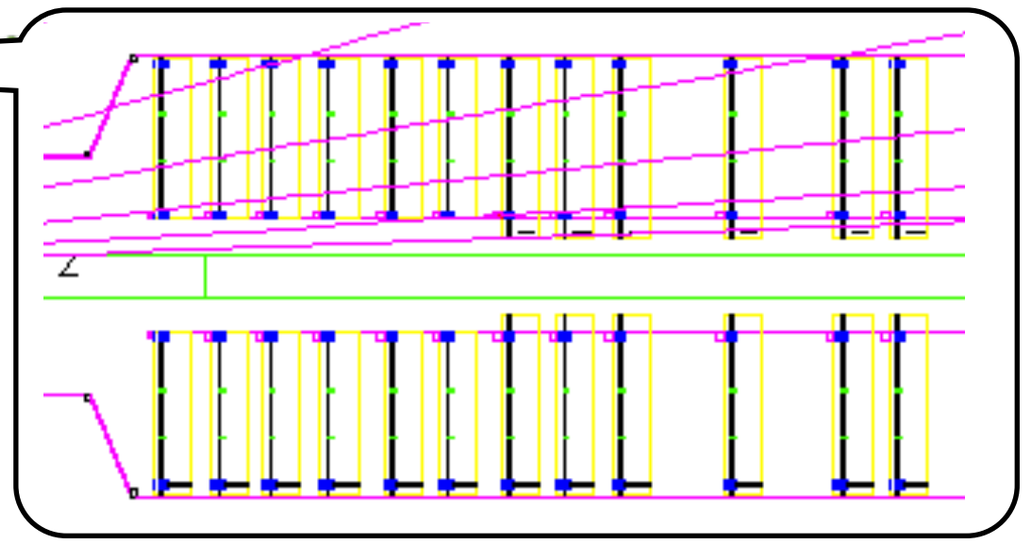


VeryFGT

- Extended tracking
- Based on FGT

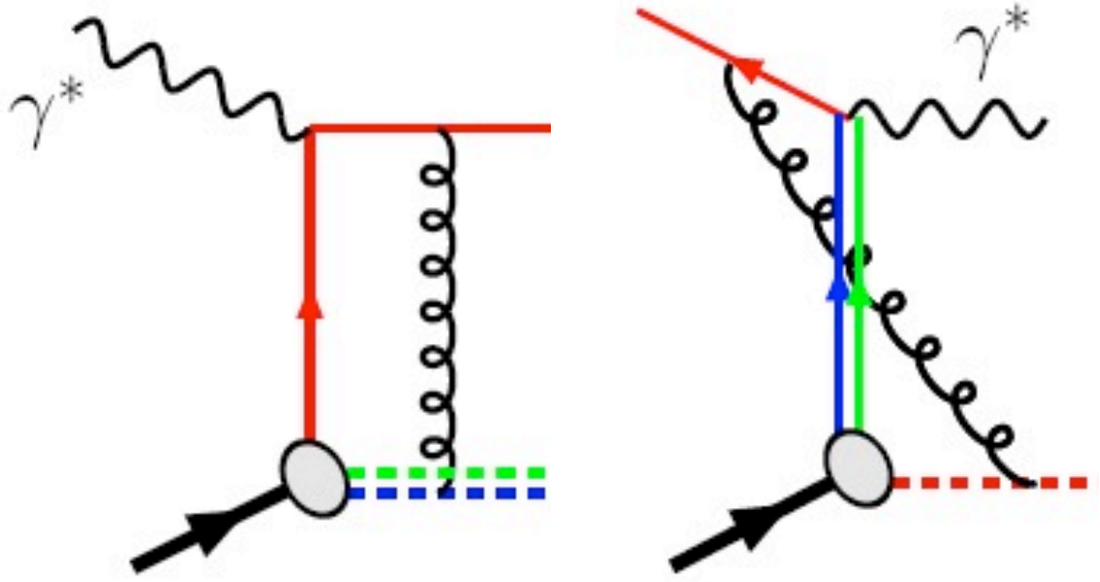


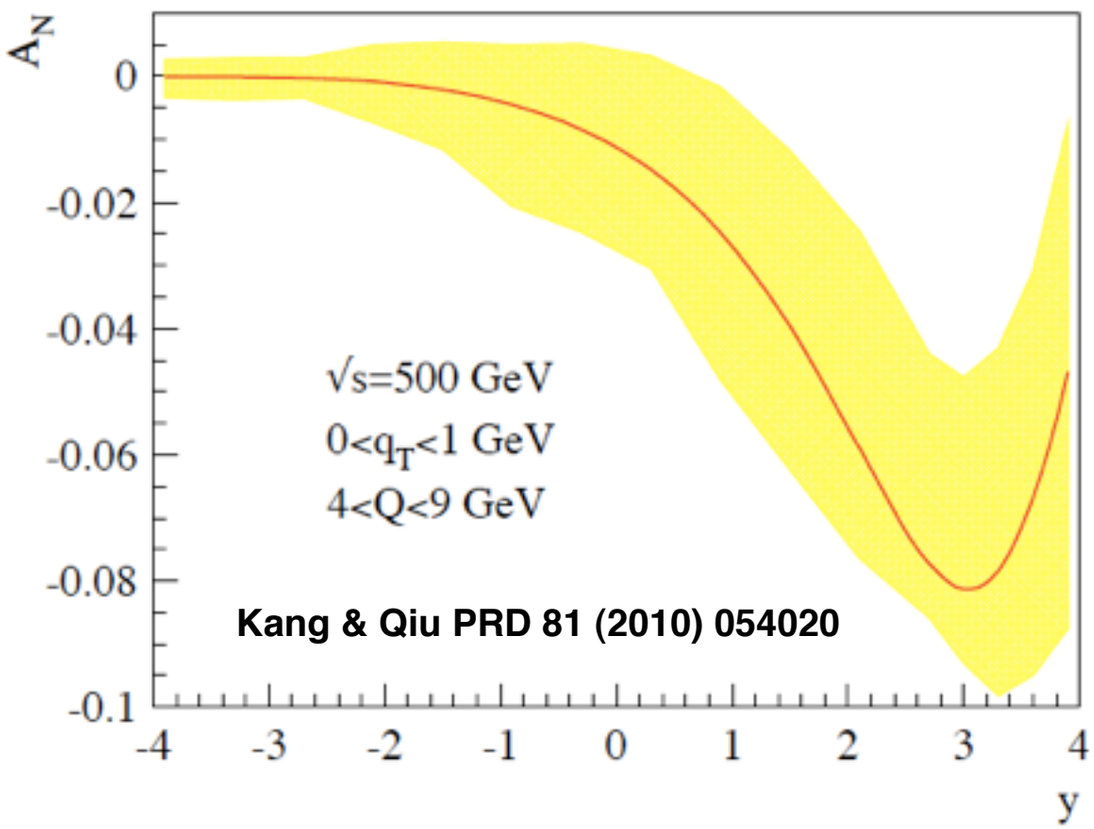
- Enables/enhances:
  - Jets
  - Collins
  - Diffractive
  - Veto for prompt photon
  - Lambda



Sivers sign change

- Drell-Yan vs. DIS:
  - **Fundamental** QCD prediction
  - opposite sign predicted $Sivers^{DIS} = -Sivers^{DY}$



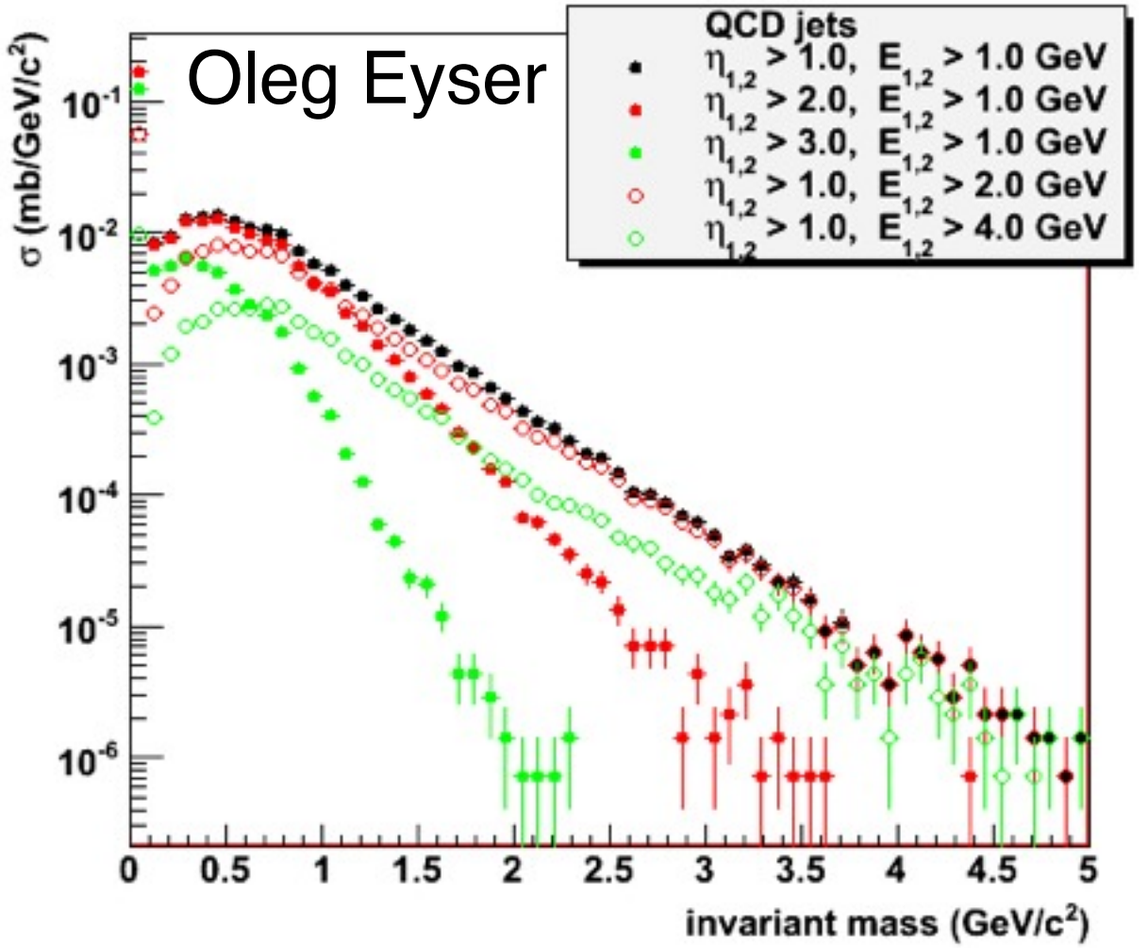


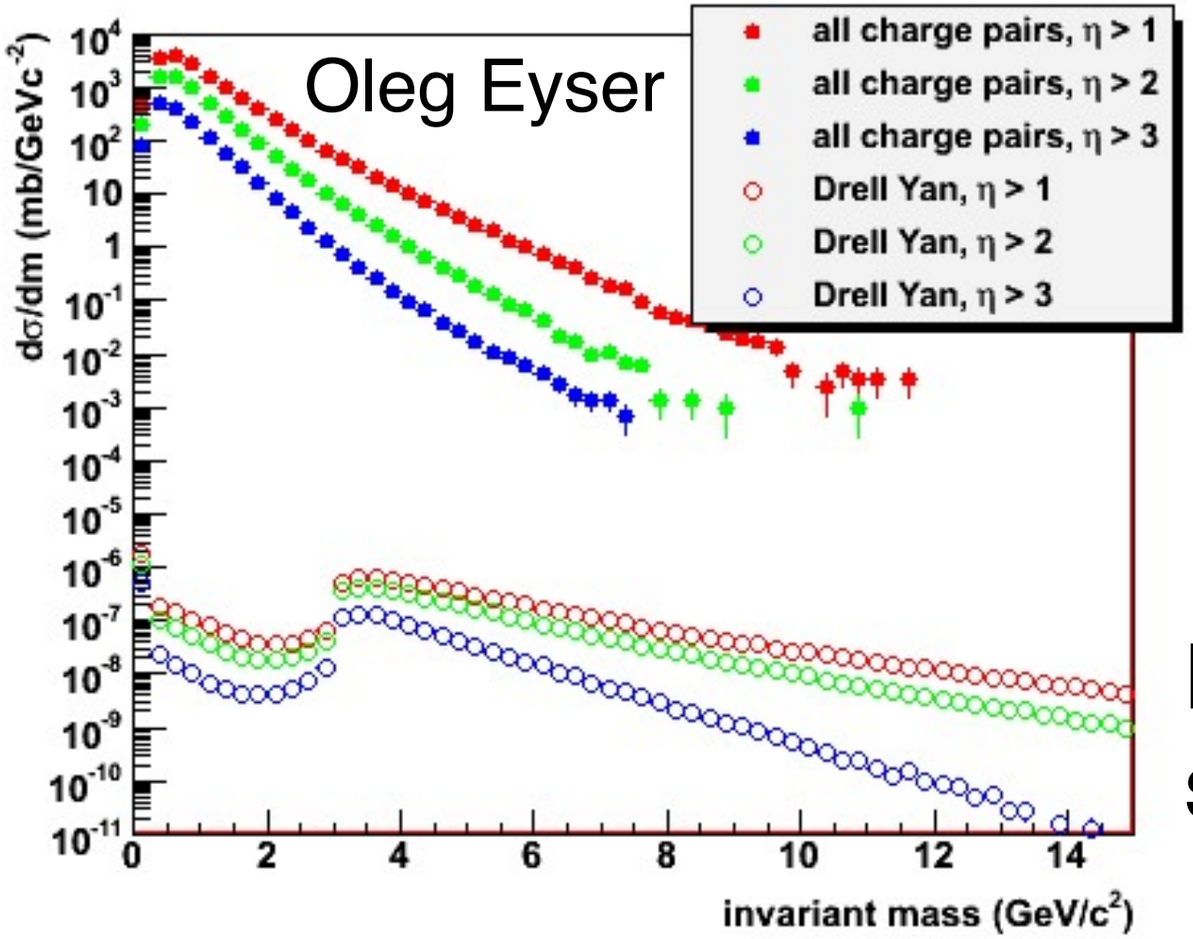
Predicted A_N^{DY} using TMD fit based on HERMES/COMPASS

Drell-Yan backgrounds

QCD

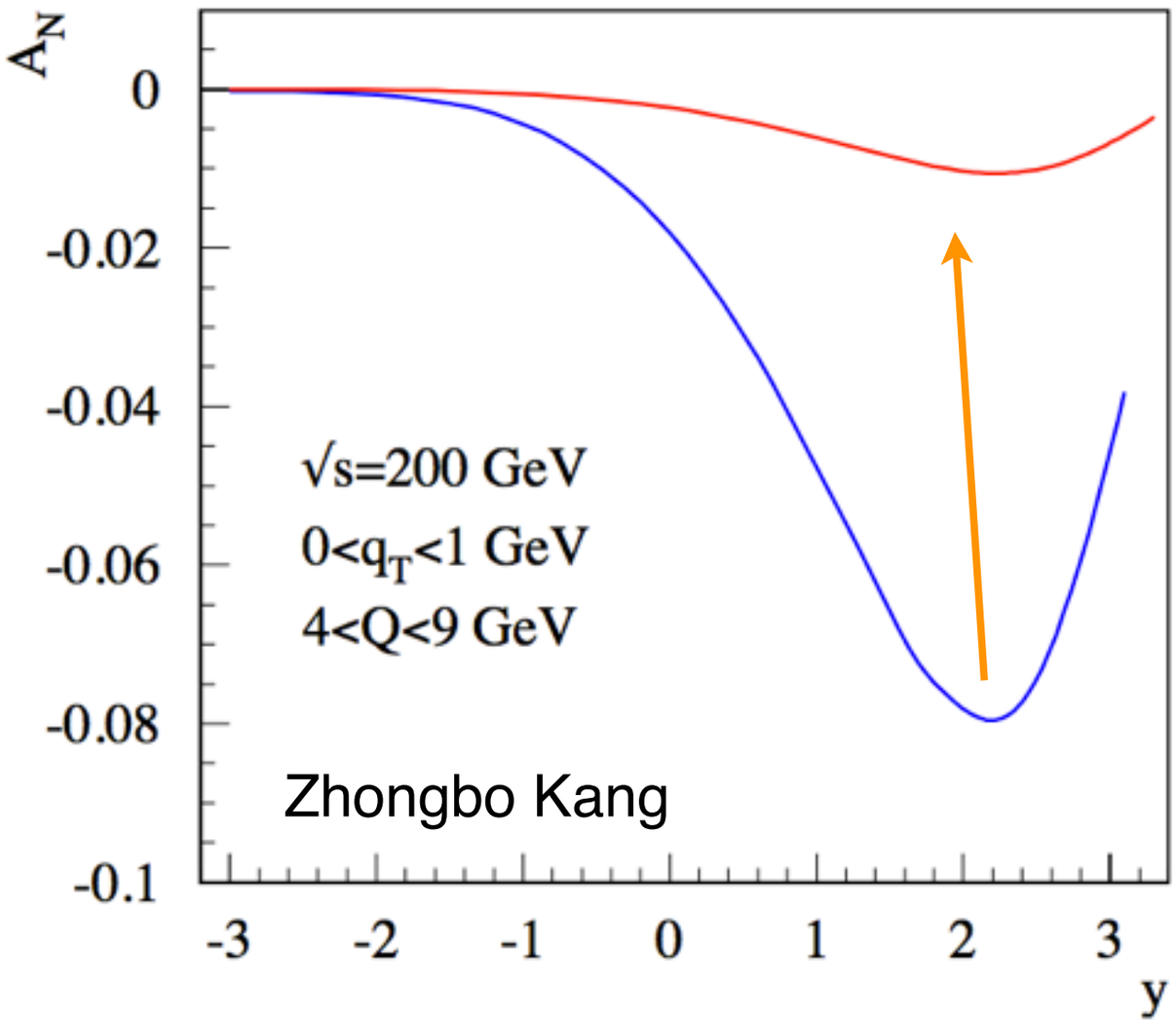
Lower at forward rapidity, large mass





Need ~10^3-10^4 hadron suppression at 500 GeV

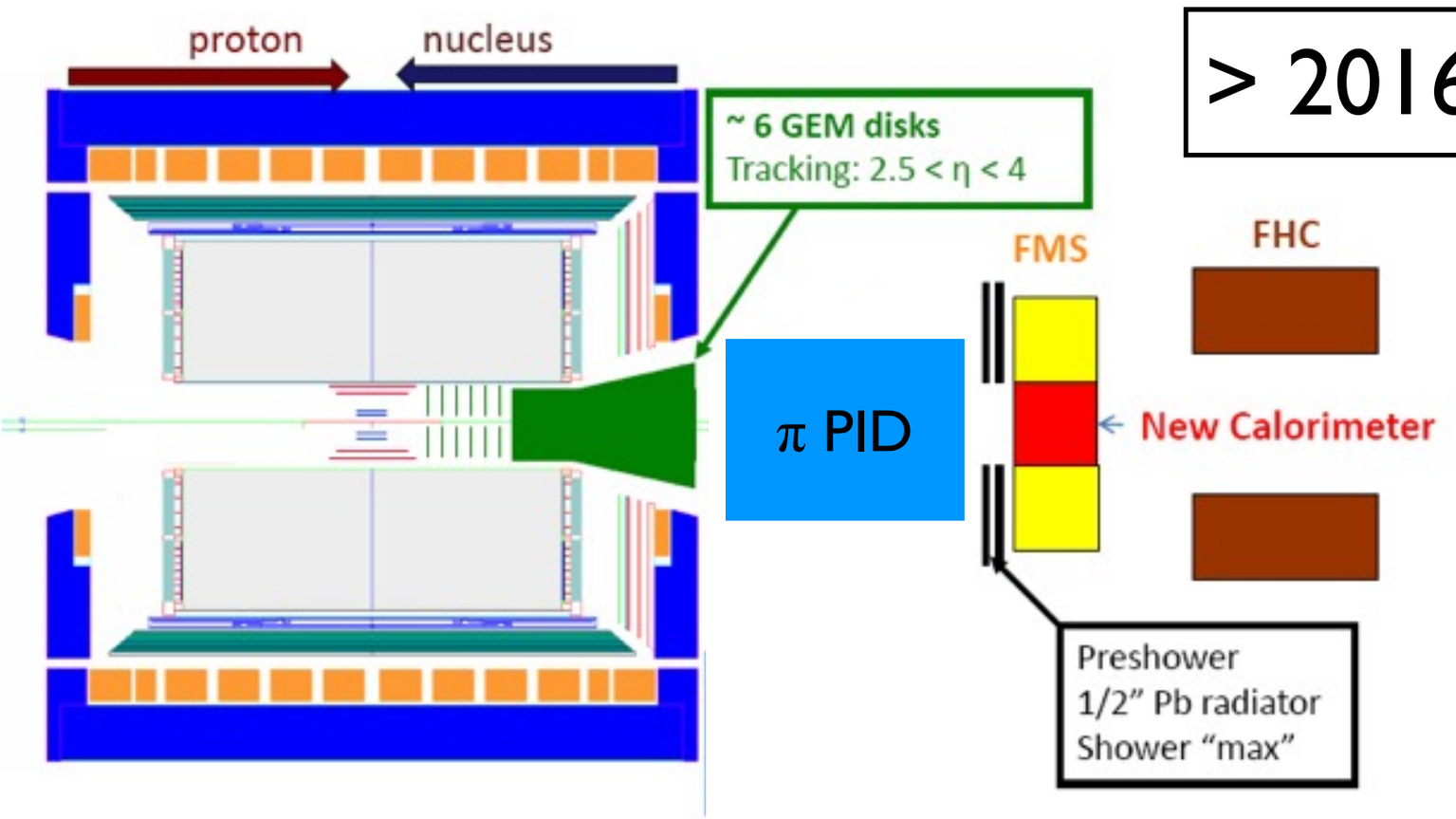
Drell-Yan



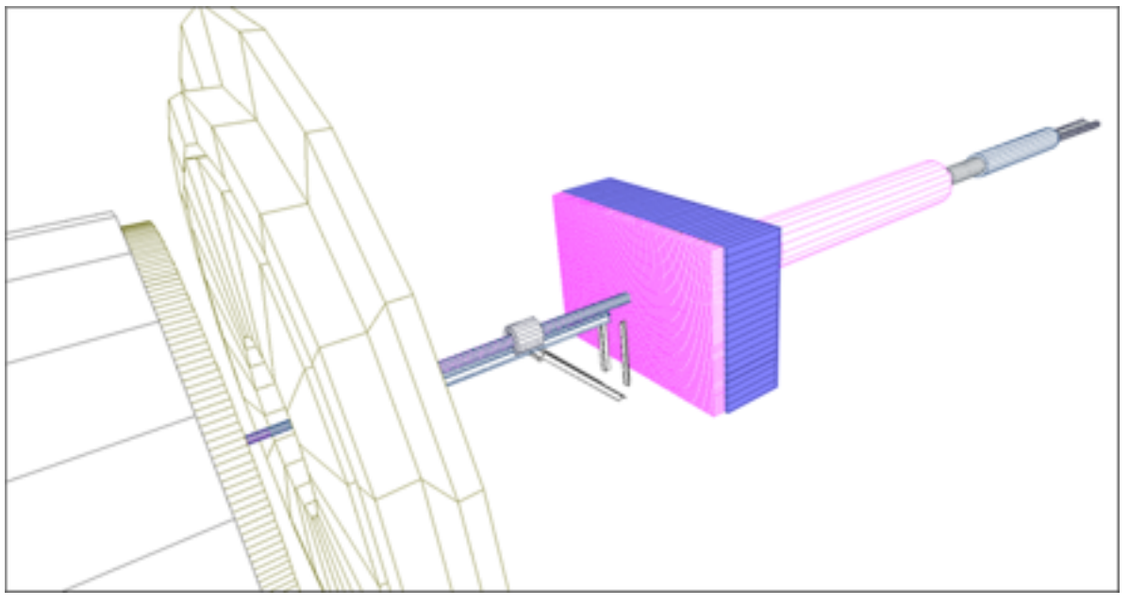
- Using Torino parameterisation:
  - bare parton model
  - evolved

If we account for evolution: is DY asymmetry actually measurable?

Forward calorimeter



> 2016



Address important forward physics goals

- pp: asymmetries
- pA: saturation

Improved EMCal, add HCal

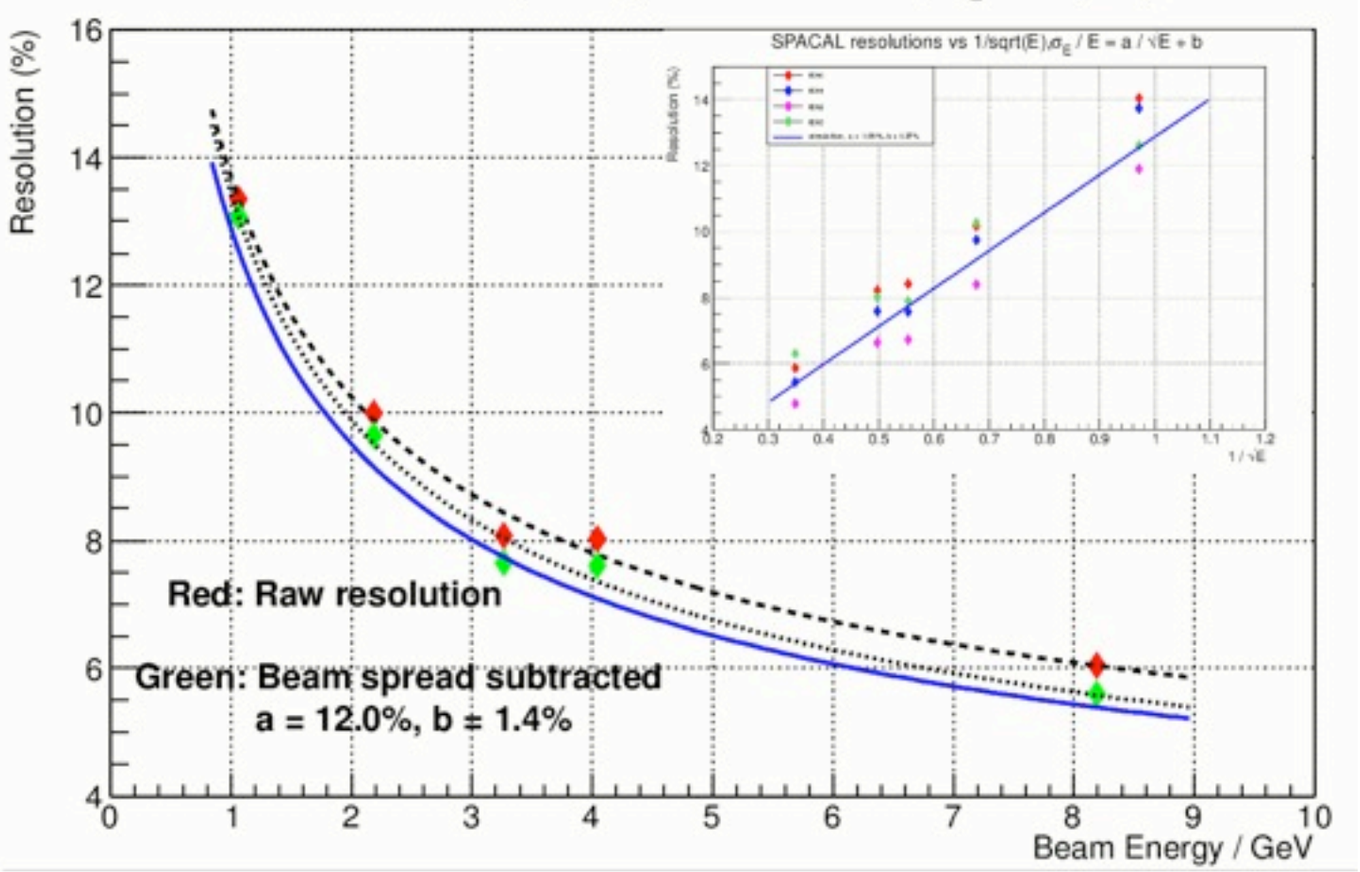
- π^0 up to 100 GeV
- e/h x1000 at 80GeV

- EMAL: SPACAL(W powder / scin)-type
- HCAL: ZEUS Sc/Pb tile

Forward calorimeter

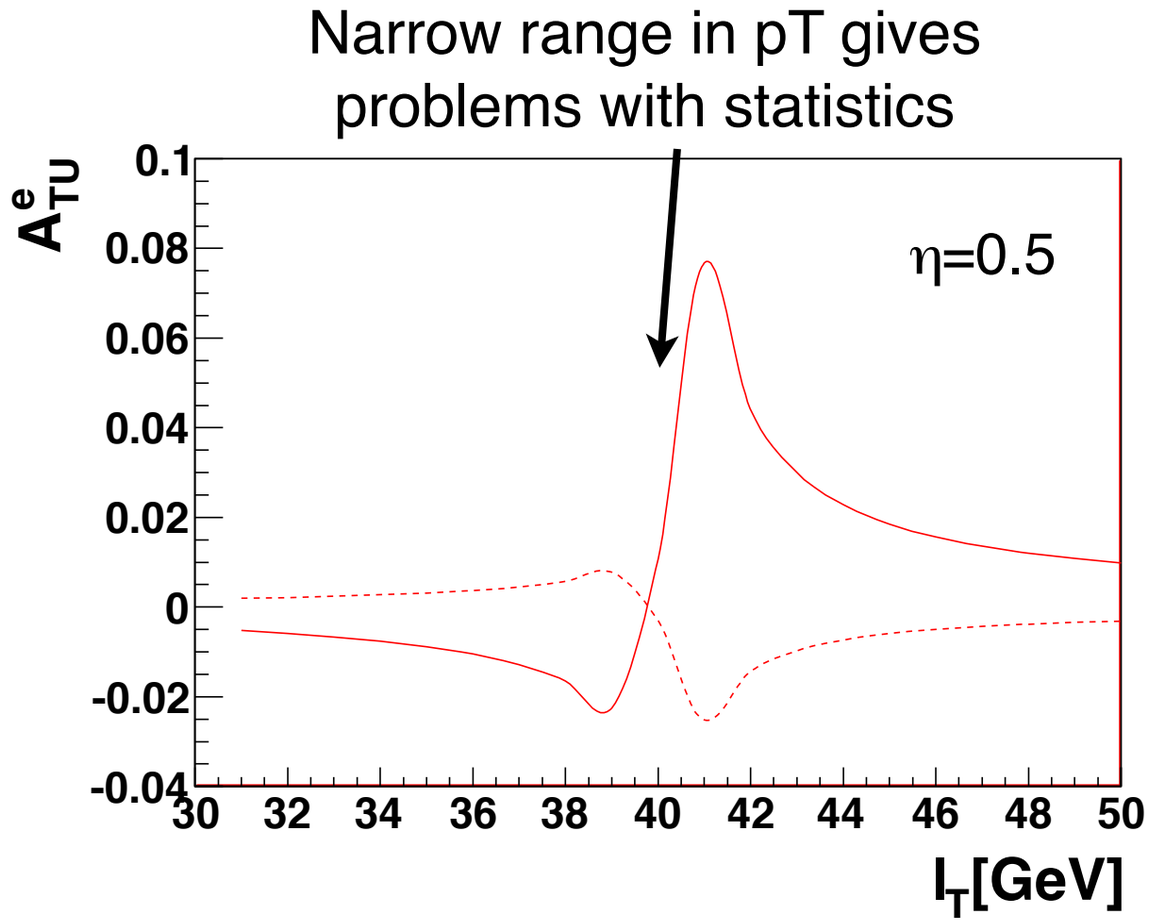
- Geant4:
  - EM 12%/sqrt(E) + 1.5%
  - single hadron 55%/sqrt(E)
  - jets 80%/sqrt(E)
- Test run matches simulation expectation well
- Other details being worked on:
  - readout scheme
  - mechanical design
- compact → EIC

Oleg Tsai
UCLA

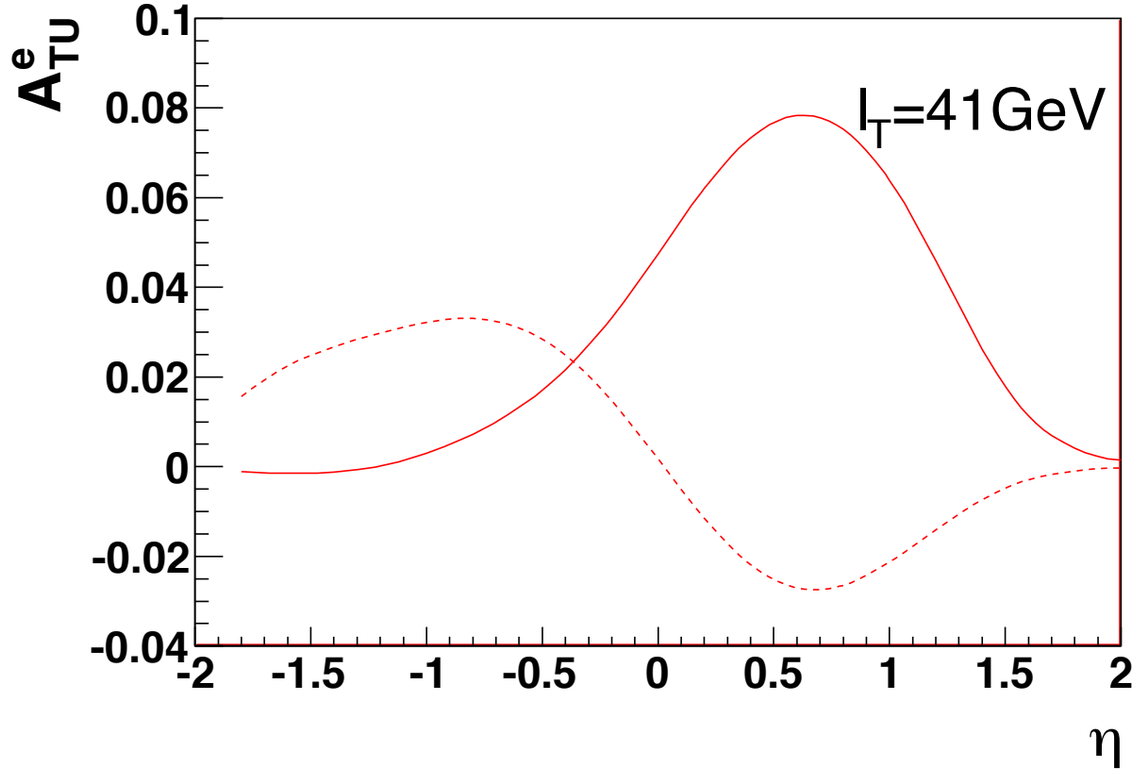


Transverse W

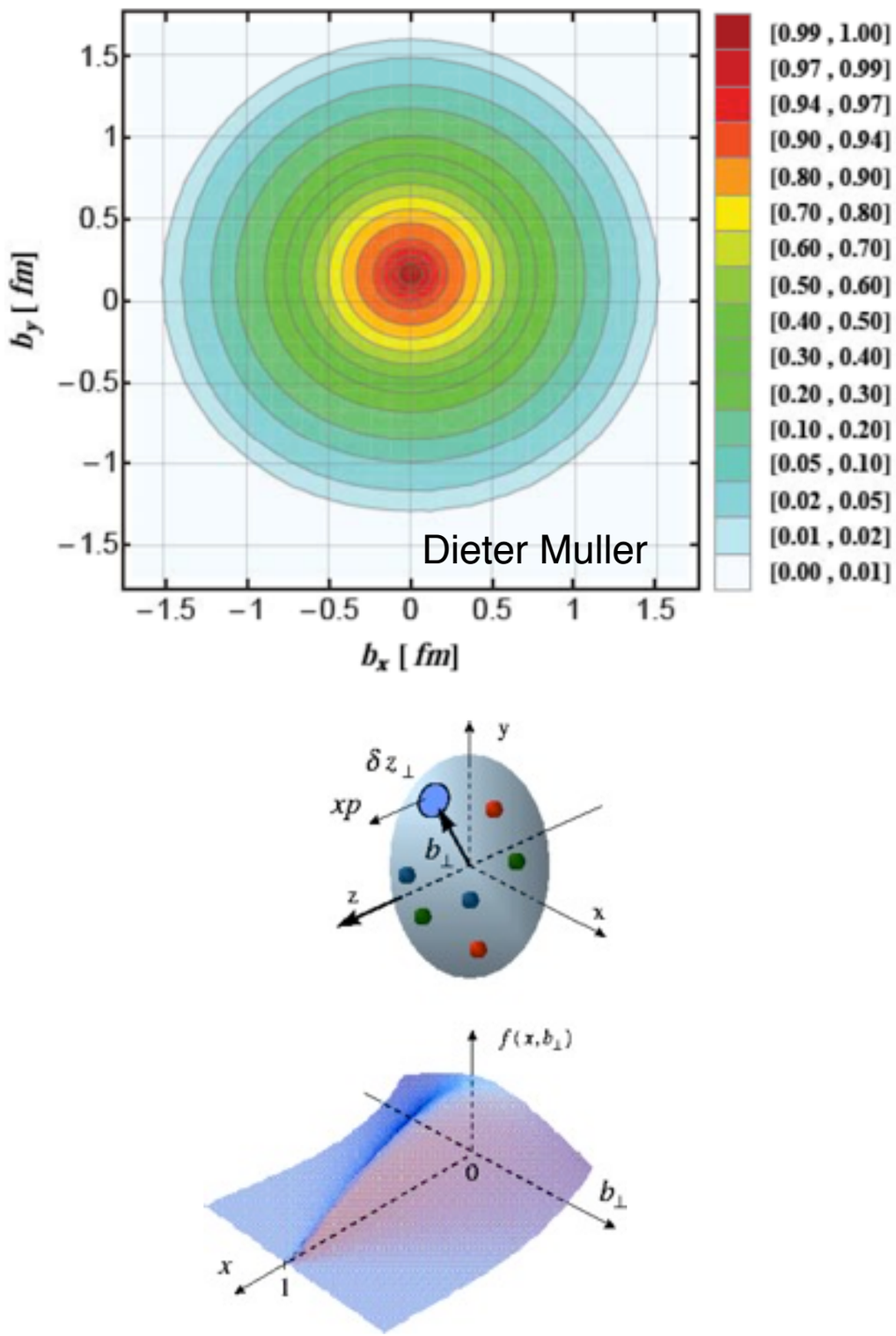
- Can we find the Sivers sign change without measuring Drell-Yan?
  - W production is Drell-Yan-like
  - $\text{Sivers}^{W} = \text{Sivers}^{DY} = -\ \text{Sivers}^{DIS}$



- Actually measure $l^{\pm}$ asymmetry: fraction of W
- Instead:
  - Z: lower statistics but cleaner signal - better channel?
  - Or “reconstruct” W?



GPDs



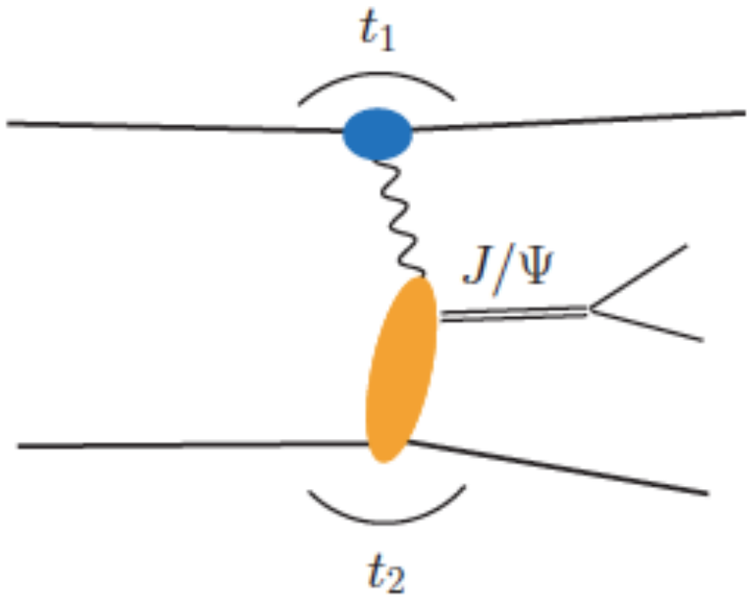
- Functions encoding info beyond 1D momentum structure
  - b distribution of partons
- Measurable via exclusive reactions
- Access to total angular momentum

$$J_q = \frac{1}{2}\int dx\, x\,[H_q(x,0,0) + E_q(x,0,0)]$$

Related to L

GPDs via UPC?

- Single γ exchange low t (large b)
  - pp becomes "γp"
- Pick up proton in Roman Pot
- Need to suppress background
- Access to GPD $E^{q,g}$ if transversely polarised target
  - need E for $J^{q,g}$
- Important precursor to eRHIC GPD programme
- polarised pA would be cool

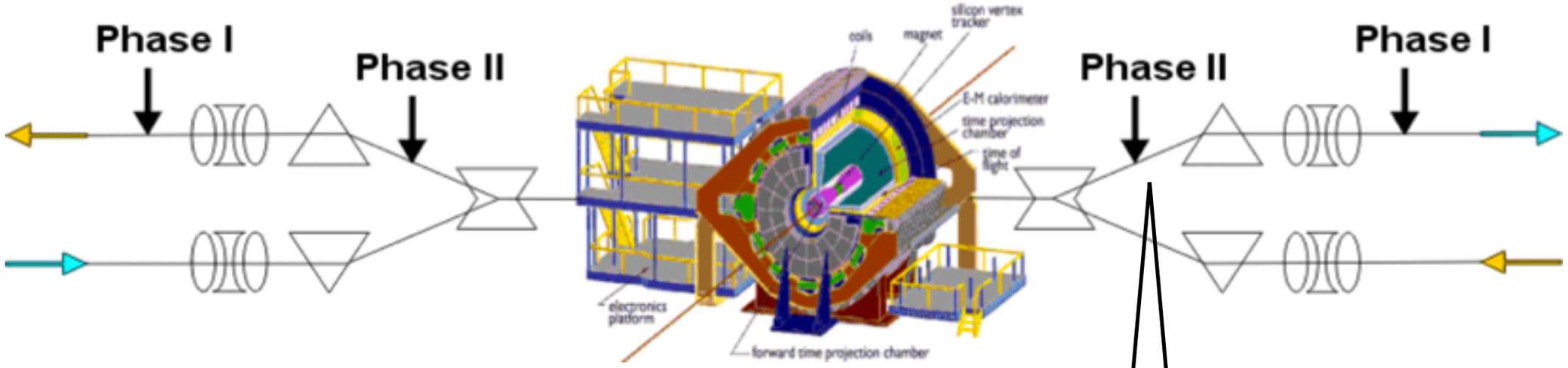


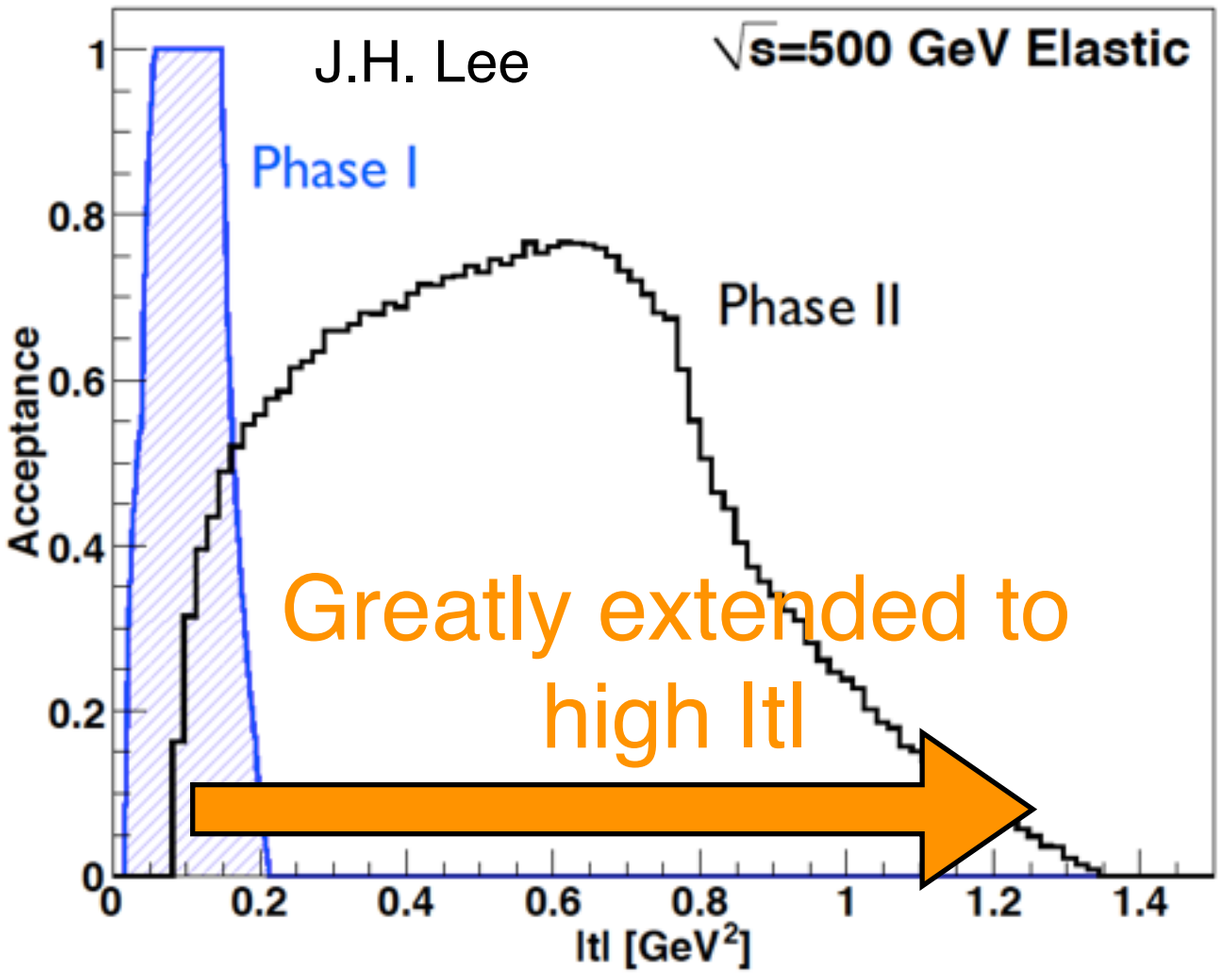
$$A_{UT} \sim \frac{\sqrt{t_0 - t}}{m_p} \frac{\mathrm{Im}(E^* H)}{|H|}$$

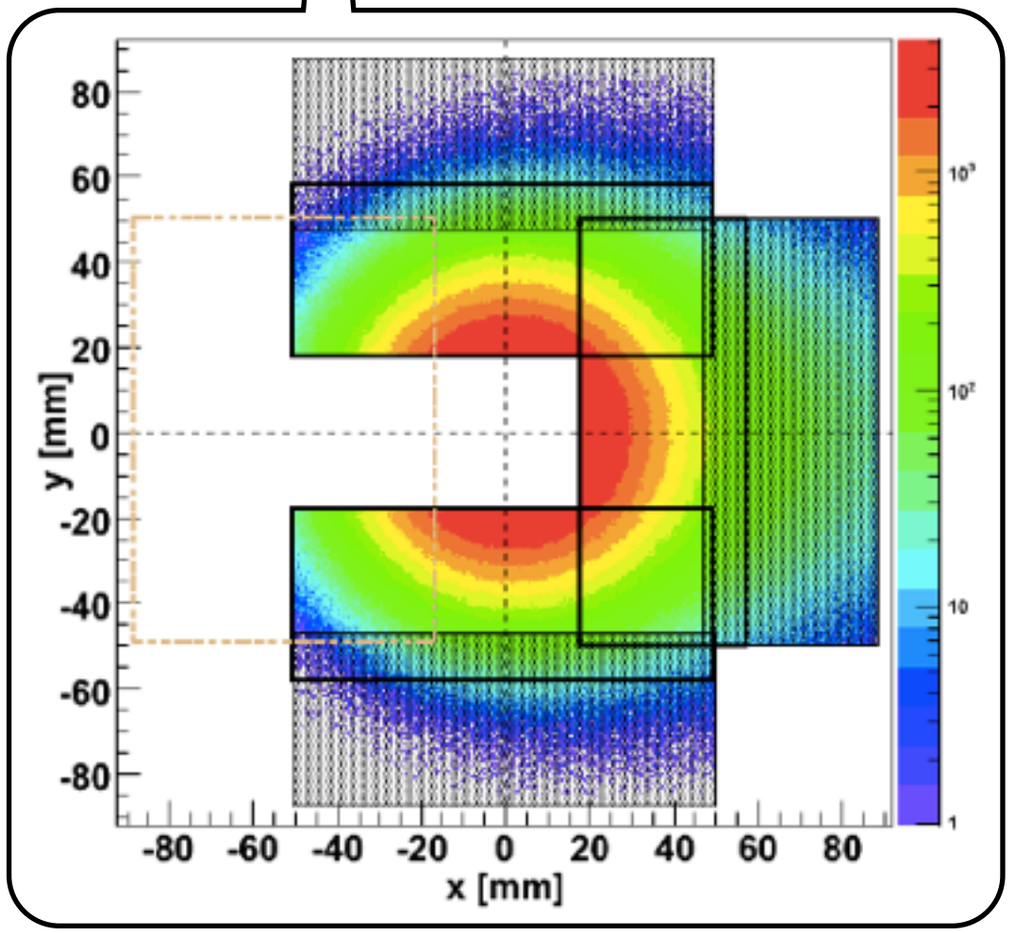
Different species probe GPDs of different flavours

ρ^0	**2u+d, 9g/4**
ω	**2u–d, 3g/4**
ϕ	s, **g**
ρ^+	**u–d**
J/ψ	**g**

Roman Pots: Phase II



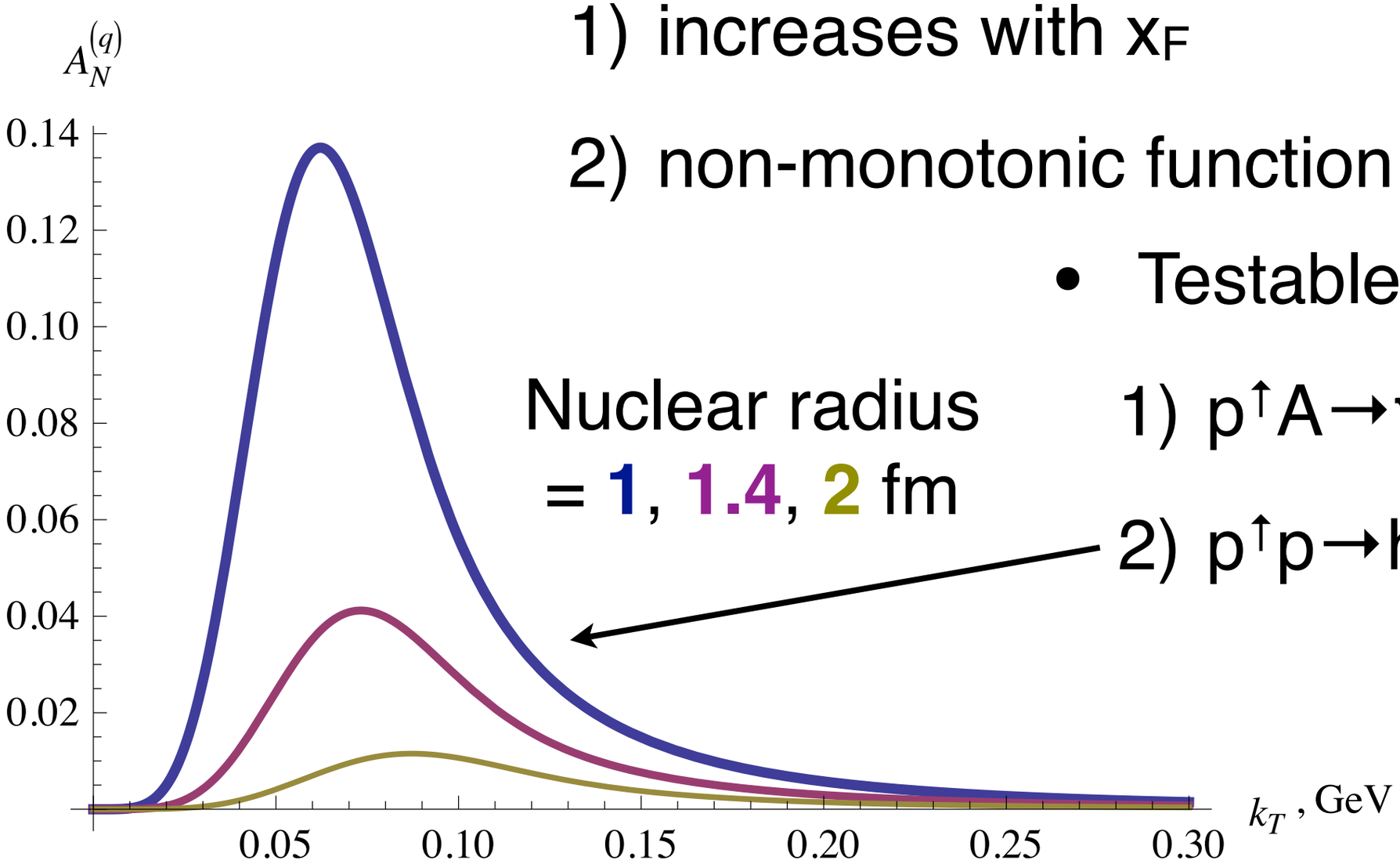




SSA in CGC?

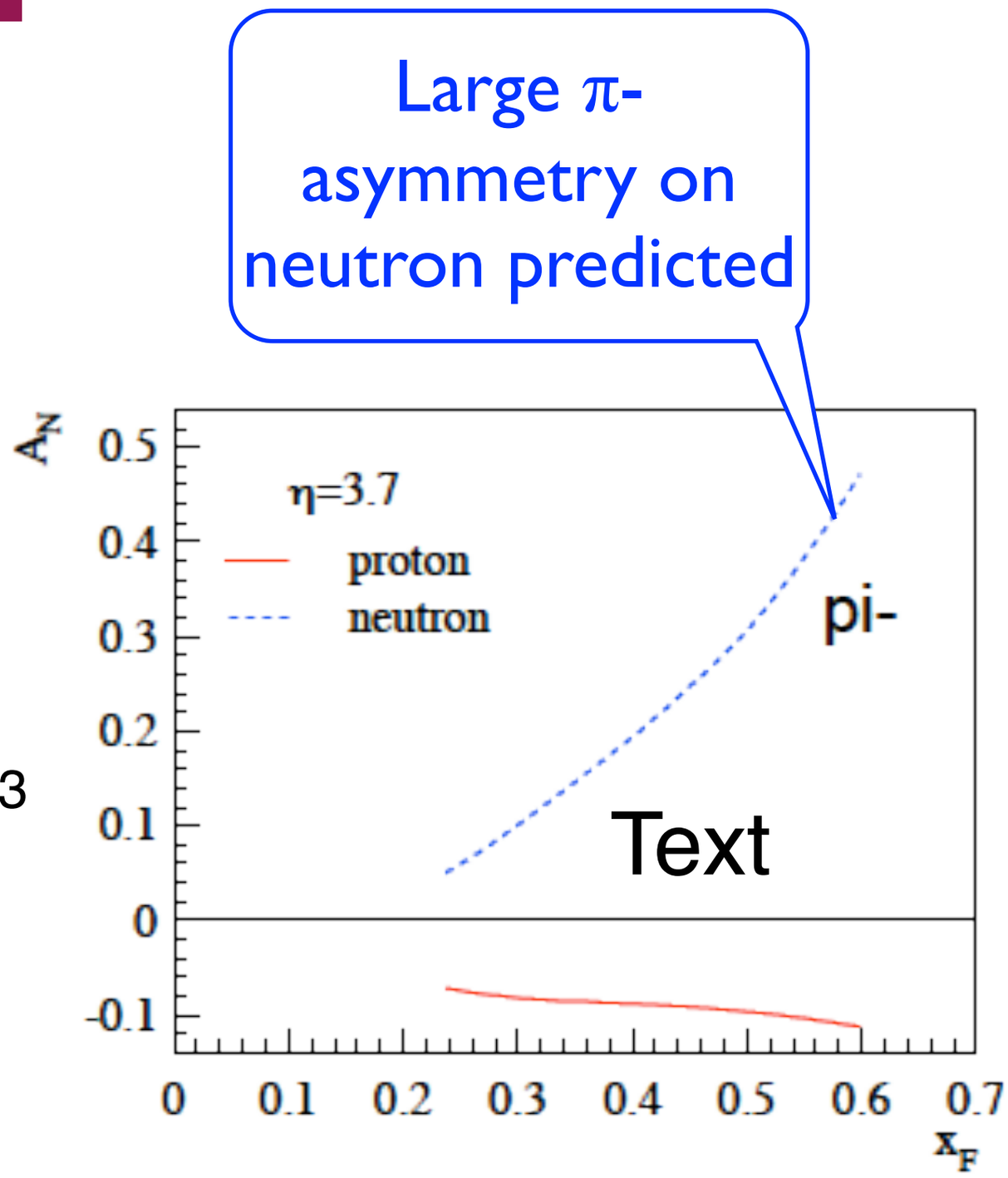
Y. Kovchegov & M. Sievert,
arXiv:1201.5890

- Predicts SSA in CGC framework
- Qualitatively matches data:
  1) increases with x_F
  2) non-monotonic function of k_T
- Testable predictions:
  1) $p^\uparrow A \to \gamma X = 0$
  2) $p^\uparrow p \to hX > p^\uparrow A \to hX$

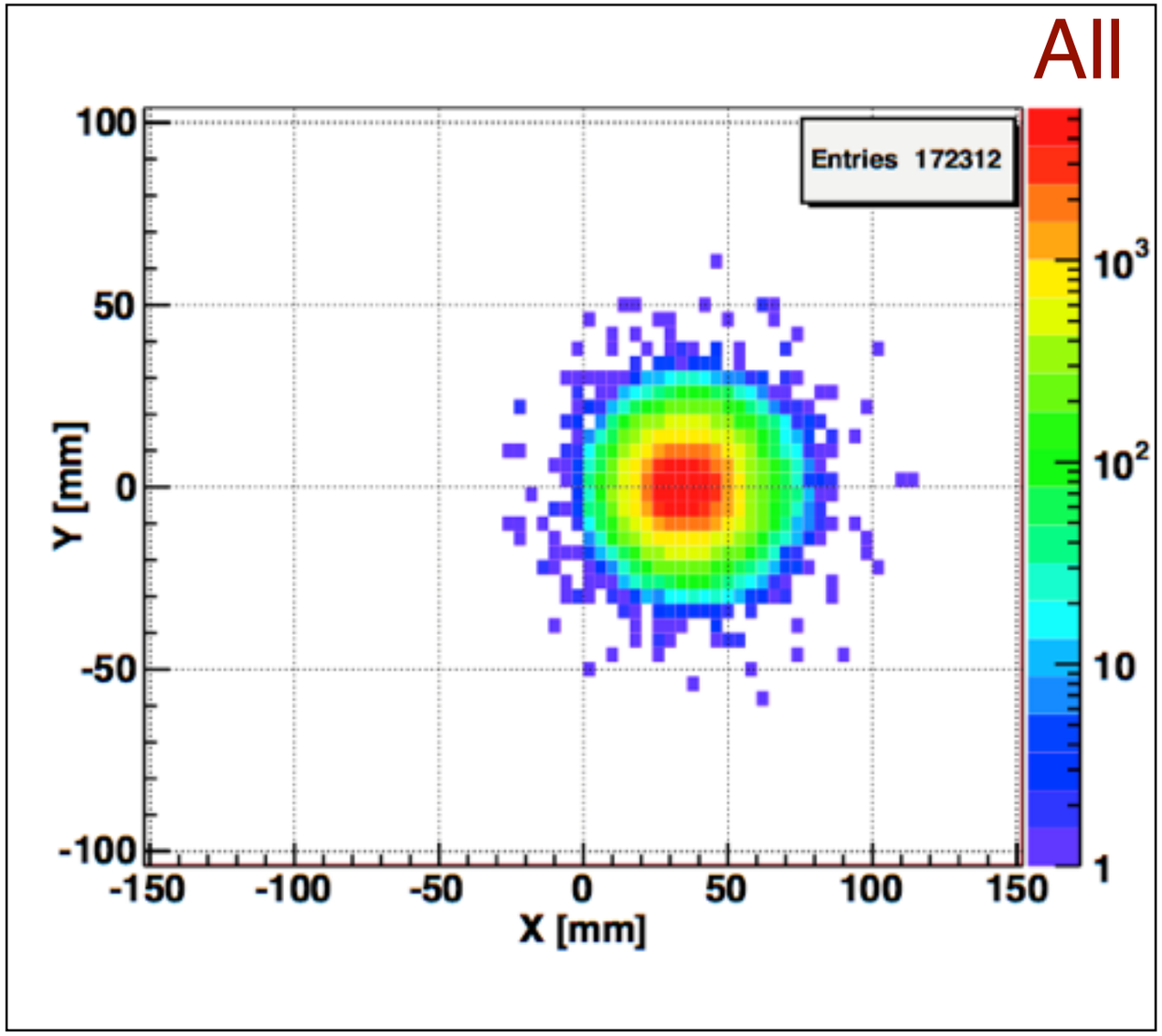


Polarised He^3

- Extract asymmetries on neutrons
- Lower centre-of-mass energy
  - 250 p → 167 GeV/n He^3
- Need to tag the spectator proton: Roman pots



Polarised He^3



- Spectator proton acceptance with current RHIC optics

Polarised He^3

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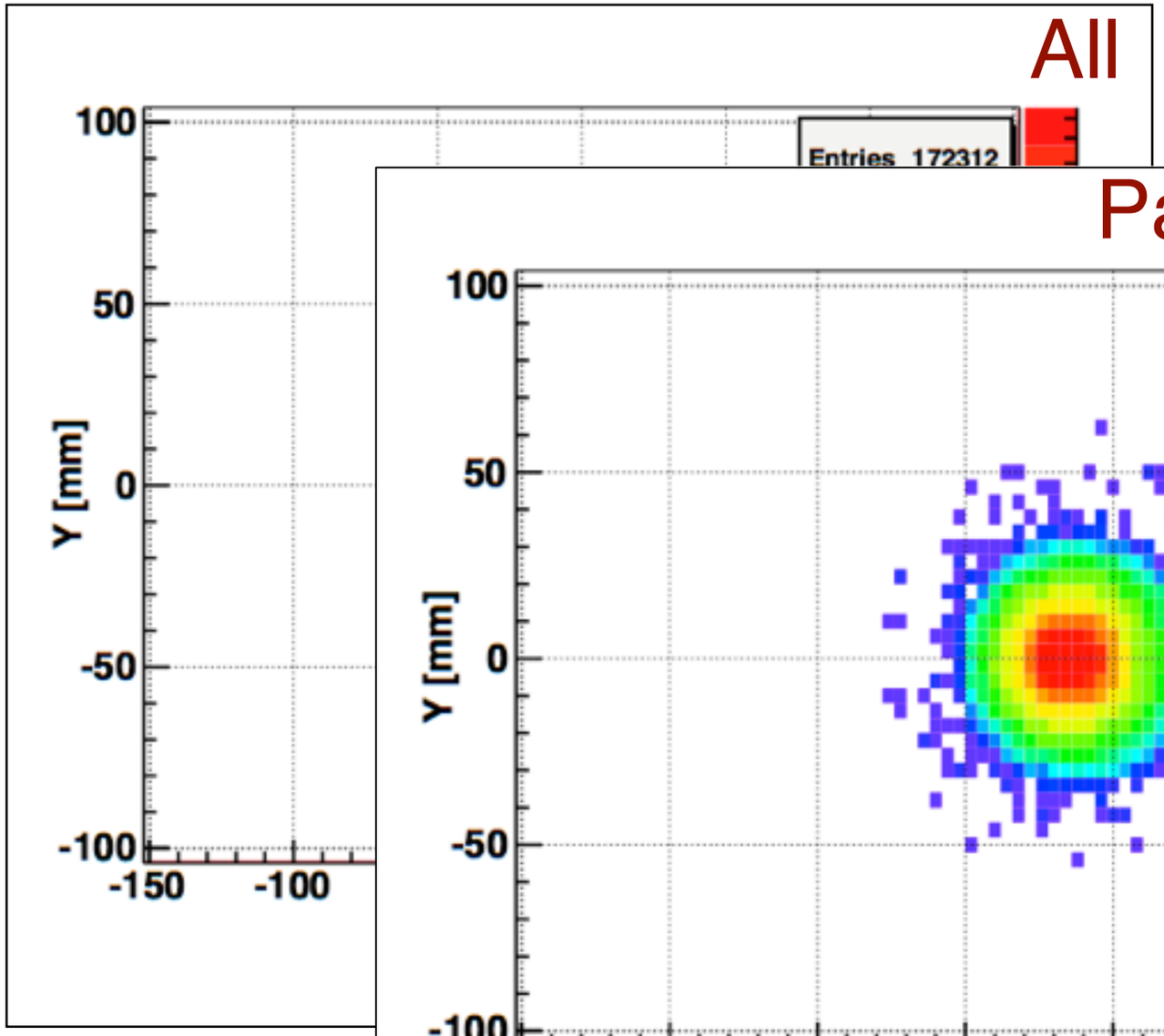

Polarised He^3

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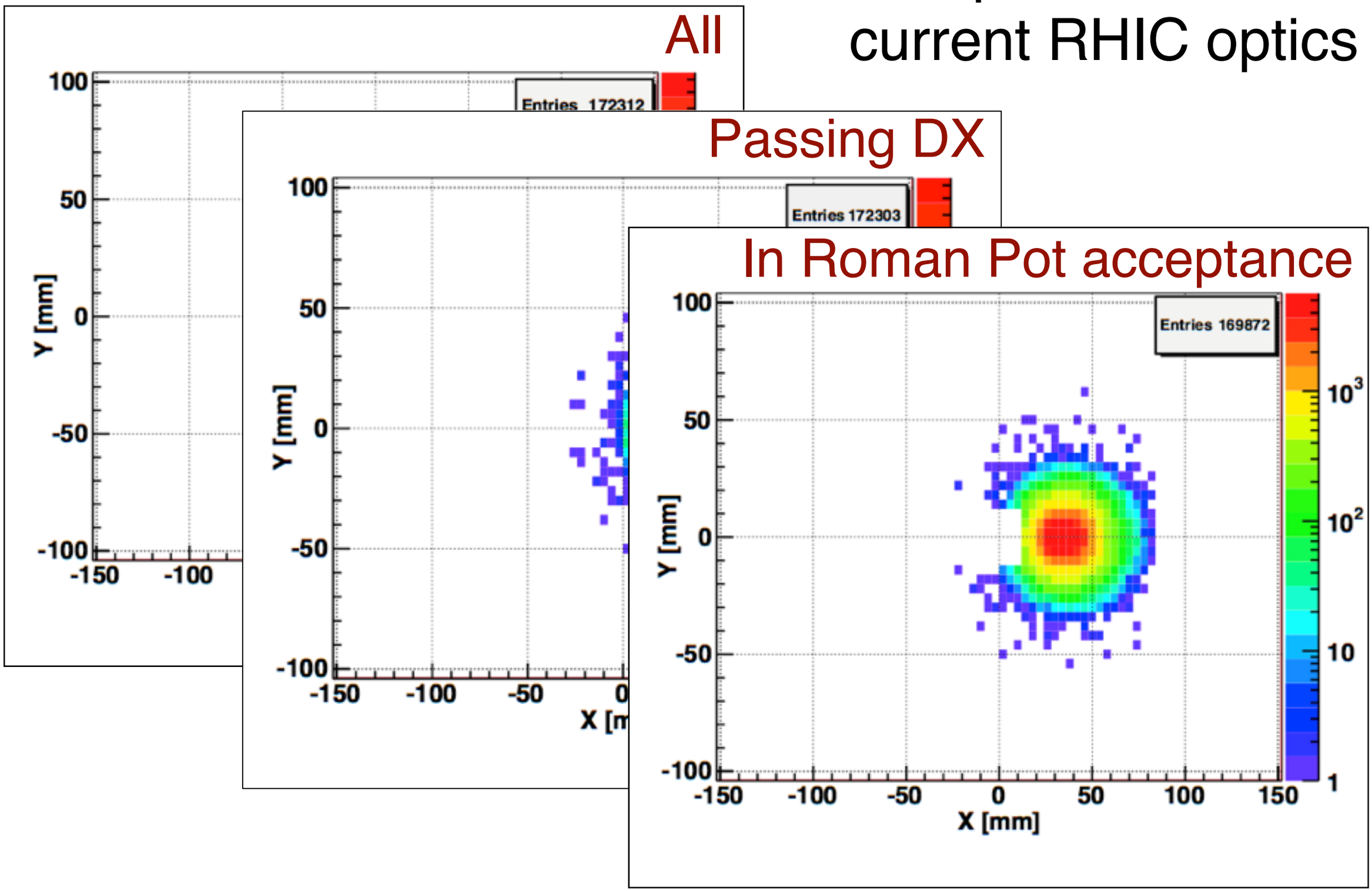

Summary

- Wide range of measurements to mid- and forward rapidity
- Many open questions remain, especially in the forward direction

- Know the physics we want to measure
- Are planning the upgrades we need to make those measurements